Scoping study of coastal and inland acid sulfate soils in the Corangamite CMA

Report to Department of Primary Industries and Corangamite Catchment Management Authority

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Cover image: Left to right, top to bottom: Exposed dry sediments Lake Gnarpurt; Drain, Hospital Swamp (L. Connewarre); Princetown Swamp; Thompson River at Breamlea; small spring on the beachfront of Corio Bay at Drysdale; section of soil core from the bank of the Thompson River at Breamlea. Photography, Warren Hicks and Rob Fitzpatrick.

Report Title:

Scoping study of coastal and inland acid sulfate soils in the Corangamite CMA

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Executive summary

CSIRO Land and Water undertook a reconnaissance study of coastal and inland acid sulfate soils within the Corangamite Catchment Management Authority region. This report presents information on the nature, distribution, impacts, management and remediation of acid sulfate soils in this region. It summarises factors generally associated with formation of pyrite and sulfuric acid in these reactive soils and the key impacts this has on a wide range of environments. The specific objectives of the study were:

⇒ to assess the extent and severity of coastal acid sulfate soils to determine if the current zoning along the coast within the Corangamite Catchment Management Authority region is sufficient to prevent problems from acid sulfate soils and potential acid sulfate soils (from development); and
⇒ to assess the extent and severity of inland acid sulfate soils to determine if the current zoning within the Corangamite Catchment Management Authority region is sufficient to prevent problems from acid sulfate soils and potential acid sulfate soils (from development).

Soils from 29 sites were inspected and 109 soil samples collected and characterised using morphological descriptors and physical properties such as colour, consistency, structure and texture. Eighty-five samples were selected for basic laboratory analyses such as soil pH, electrical conductivity (1:5 soil:water) and peroxide pH, and fifty-nine samples selected for detailed analyses including:

⇒ chromium reducible sulfur, carbonate content and acid-base accounting;
⇒ mineralogical analyses i.e. powder X-ray diffraction and scanning electron microscopy; and
⇒ geochemical analyses using X-ray fluorescence spectroscopy.

A wide range of acid sulphate soil types containing sulfidic materials (pH >4 with pyrites) are currently developing in a wide range of landscapes in the Corangamite Catchment Management Authority region, often in association with areas undergoing salinisation. No actual acid sulphate soil was identified. However, the Princetown area has concentrations of reduced inorganic sulfur that are some of the highest recorded in Australia and these represent an extreme acid sulphate soil risk. Additionally, levels of trace metals and metalloids were found and their ecotoxicity needs to be assessed. Oxidation of sulfidic materials and monosulfidic black ooze following the lowering of water tables or soil disturbance is contributing to degraded saline seepages and poor stream water quality.

The methodology used helped verify the acid sulfate soil risk classes, develop treatment categories and recommend management options.

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1 Introduction

CSIRO Land and Water is pleased to present to the Department of Primary Industries (DPI) and the Corangamite Catchment Management Authority (CMA) our scoping study of coastal and inland acid sulfate soils (ASS) in the Corangamite CMA region. The study was commissioned in August 2006 by Mr Troy Clarkson, Soil Health Program Manager, Department of Primary Industries (DPI) Geelong, as a research and investigation component in the Corangamite Soil Health Strategy (SHS; CCMA, 2006). The work builds on previous studies within parts of the region (e.g. City of Greater Geelong; Cox *et al*., 2005)

1.1 Background

The Corangamite SHS was completed in October 2006 and provides the framework for investment in regional soil health over the next decade. The SHS was accepted and endorsed by the Board of the Corangamite CMA in February 2007 and will be implemented over the next few years. The SHS is a component of the Corangamite Regional Catchment Strategy, and its implementation will be guided by the Salinity and Soils Operational Portfolio Group who report to the Corangamite Regional Implementation Committee within the CMA.

The Corangamite SHS has identified 20 priorities for investment, based on an asset-threat model which included an assessment of risk to public and private assets. Among the highest aggregate risk values was the potential threat to all classes of assets by ASS. However, it is uncertain if the risk has been overstated, as there is little evidence of past or current impact of ASS on catchment assets in the Corangamite region.

The risk of damage to assets was assessed as highest in the Bellarine and Thompson Landscape Zones of the Corangamite region. To validate this assessment, CSIRO were commissioned by the DPI and CMA to undertake a preliminary investigation of the ASS risk in the City of Greater Geelong. The conclusion of that 2005 preliminary study was that although ASS are present in the Geelong region, they are mostly confined to Public Conservation and Resource areas and are therefore unlikely to be disturbed by urban development (Cox *et al*., 2005). One exception to this was in the industrial zoned area of Point Henry, where the presence of ASS were verified, however the risk was considered marginal due to the presence of sufficient carbonate materials (shell beds) to neutralise any acid that may be generated.

However, the question remained regarding the potential risk to catchment assets from ASS in other areas of the Corangamite region. In particular, since the publication of maps showing the possible distribution of both coastal and inland ASS, there has been growing awareness of ASS as a potential liability within the region's municipalities. The authorities responsible for strategic planning, such as the CMA, DPI, Department of Sustainability and Environment (DSE) and the municipalities, need to be informed of the presence of potential ASS so that any proposed land-use or development is appropriately considered. Indeed, if the ASS threat is verified, statutory planning regulations may be implemented to manage the risk. Similarly, managers of public assets and infrastructure, such as Parks Victoria, water authorities and utility companies, also need to be informed of any potential risk.

Therefore, one of the initial actions in the Corangamite SHS is to validate the perceived risk to assets from potential ASS in the entire Corangamite region. This scoping study was commissioned to fulfil that task.

1.2 Aims, objectives and scope

The aim of this scoping study is to verify the presence (or absence) of potential ASS in the Corangamite region and assess the risk they might pose to catchment assets.

To achieve this aim, two objectives were identified:

⇒ to assess sites in the Corangamite CMA where: (i) salinity plus waterlogging; (ii) salinity plus natural lake/wetland environments; or (iii) recent (Holocene) marine conditions, indicated the likely presence of ASS;

⇒ to identify appropriate mitigation strategies for identified hazards in an ASS management plan.

In its scope, this study is a reconnaissance investigation based around a one week field sampling exercise, and should not be regarded as a comprehensive investigation of the entire Corangamite CMA region. The field sites were selected on the basis of local and expert knowledge and there are certainly many more sites where potential ASS exist, but were not included in this investigation. To investigate every potential site where ASS might occur was clearly not possible in this initial survey.

The investigation was undertaken by a team with both local expertise and international experience in identifying and assessing ASS. Assistance was sought from and given by scientific colleagues at Primary Industries Research Victoria (PIRVic) who are also expert in ASS in Victoria.

This report presents results of fieldwork, laboratory analyses and provides recommendations for mitigation strategies in areas identified with ASS potential.

2 Acid sulfate soils

2.1 Coastal acid sulfate soils

The purpose of this section is to briefly explain: (i) what are sulfidic and sulfuric materials, (ii) what risks they pose to the environment under certain conditions and (iii) awareness and economic impacts of ASS.

Coastal ASS form in coastal estuaries and mangrove swamps because these waterlogged or highly reducing environments are ideal for the build-up of the mineral iron pyrite (FeS_2). ASS are environmentally unfriendly soils when they are exposed to air by disturbance or over-drainage, and then rewetted. They become strongly acidic (pH <3.5) and acid drainage water is produced. This acid, together with toxic elements that are leached from sediments can kill fish, contaminate shell fish and drinking water or groundwater, and can corrode concrete and steel in underground pipes and building foundations.

The impacts of disturbing ASS can be measured in terms of:

⇒ Poor water quality with loss of amenity, damage to estuarine environments and reduction of wetland biodiversity;
⇒ Loss of fisheries and agricultural production;
⇒ Additional maintenance of community infrastructure affected by acid corrosion; and
⇒ The need for rehabilitation of disturbed areas to improve water quality and minimise impacts.

2.2 Materials in acid sulfate soils

Sulfidic materials are mostly accumulations of iron sulfide minerals in sediments and soils. Iron sulfide minerals are one of the end products that form as part of the process of sulfate reduction (i.e. the use of SO_4^{2-} instead of O_2 during microbial respiration). Sulfate reduction is a natural process that occurs in virtually all lakes, rivers, wetlands and oceans. However, the quantities of sulfidic material that will accumulate in a given environment are a function of many factors.

The key requirements for high rates of sulfate reduction and sulfide accumulation are:

⇒ high concentrations of sulfate in surface or groundwater;
⇒ saturated soils and sediments for periods long enough to favour anaerobic conditions; and
⇒ availability of labile carbon to fuel microbial activity.

Saline groundwater and seawater usually contain a large amount of sulfate. Thus, estuaries, drains, intertidal wetlands and salinised inland wetlands should be expected to accumulate some sulfides in their sediments over time.

Monosulfidic black ooze: Monosulfidic black ooze (MBO) is readily observed in creeks, rivers and wetlands. The high nutrient environment and the activity of algae and micro-organisms create a reductive environment resulting in the formation of black smelly, iron and other sulfides. MBO is very reactive if exposed to oxygen and produces acid; however, provided the materials remain anoxic, they are benign. If disturbed e.g. by storm events or human activity and suspended in the water column, MBO cause deoxygenation. Additionally disturbance can also generate acid, although in many cases, there is sufficient alkalinity in the water or neutralising capacity in the soil to neutralise the acid.

Sulfuric materials: When sulfidic materials are drained and exposed to air, they oxidise and produce sulfuric acid (Dent and Pons, 1995). If the amount of acidity produced exceeds the buffering capacity of water and sediments, acidification occurs. Prior to draining, materials that can cause acidification are called sulfidic materials (i.e. potential acid sulfate soil materials or PASS). Once sulfidic materials are drained they may transform to sulfuric materials (i.e. actual acid sulfate soil materials or AASS).

2.3 What risks do sulfidic and related materials pose for the environment?

A number of potential environmental risks associated with sulfidic materials can occur when they are disturbed (i.e. resuspended in the water column, drained or excavated). These include:

- ⇒ **Acidification and elevated metal concentration:** In addition to lowering pH, activation or oxidation of sulfidic materials can lead to significant increases in dissolved metal concentration in surface water, including toxic species such as aluminium, iron and other metals that may be present in the soil (e.g. arsenic, lead, zinc, copper or cadmium). The increase in solubility of metals under acidic conditions may be more harmful to biota than the low pH itself.

- ⇒ **Water column deoxygenation:** When sediments rich in monosulfides are resuspended, they will rapidly oxidise, potentially removing most of the oxygen from the water column (Sullivan et al., 2002). This can lead to fish kills, especially in enclosed areas such as marinas or estuaries. In Eastern Australia, the resuspension of sulfidic sediments (containing MBO) during the flushing of drains by high runoff events has been linked to deoxygenation (Sullivan *et al*., 2002).

- ⇒ **Noxious odours:** Foul offensive odour problems have been encountered near areas rich in sulfidic materials. For example, St Kilda, north of Adelaide is sometimes plagued with noxious smells during the warmer months, when sulfidic materials partially dry during low tide. These offensive smells occur when sediments extremely enriched in sulfides are exposed to the atmosphere. Hydrogen sulfide production (H_2S – the rotten egg smell) by drying sulfidic materials is thought to be a significant cause of the foul smells. Drying sulfidic materials also produces sulfur dioxide (SO_2). Aside from the foul odour problem, H_2S and SO_2 are also of concern for human health at high concentrations e.g. in confined spaces such as excavations. A number of malodorous organic-S gases (such as dimethyl oligosulfides) can also be produced under the conditions favourable to H_2S production (Franzmann *et al*., 2001, Lomans, 2002).

2.4 Awareness and economic impacts

It is vital for all developers, community groups and councils to be aware of the many impacts that result from disturbance of sulfidic materials as these have important consequences for environmental, engineering, economic, and quality of life perspectives. Because of the extensive level of existing disturbance and development pressure in many areas across Australia this could be a critical natural resource management issue for many areas. This is understandable when one adds up the documented potential of sulfidic material disturbance to destroy wetlands, acidify and deoxygenate waterways and estuaries, increase the incidence of fish kills and disease, contaminate valuable groundwater resources and public park space, facilitate the mobility and accumulation of heavy metals, corrode, attack and destabilise roads, concrete and steel infrastructure, stimulate blooms of marine blue-green algae, decrease the agricultural productivity of land, increase odour problems and increase mosquito and arbovirus incidence.

3 Field program

The study was conducted within the boundaries of the Corangamite CMA in southwest Victoria. The CMA covers and area of around 1.3 million hectares and extends from Queenscliff (east) to Peterborough (west), and the Great Dividing Range (north) to Cape Otway (south). The area includes the major provincial cities of Geelong and Ballarat.

CSIRO Land and Water conducted a field investigation in conjunction with Dahlhaus Environmental Geology Pty Ltd from 18th to 22nd October 2006. Sites were selected on the basis of (i) CSIRO's existing coastal and inland ASS knowledge of the areas, (ii) National Atlas of ASS on the Australian Soil Resource Information System (ASRIS), (iii) soil and vegetation surface features, and (iv) GIS-based analysis using a digital elevation model, topographic attributes and aerial photographs. Inland areas of interest were identified mainly using a desktop analysis (GIS) to identify areas at risk from dryland salinity and waterlogging, two factors likely to result in the occurrence of inland ASS. Inland saline lakes were also examined. Coastal sites were mainly selected using information supplied by CMA officers, PIRVic colleagues and existing information from the Australian Atlas of Coastal ASS.

A wide range of geomorphic landscapes were considered in the site selection, including the streams, lakes and wetlands of the Victorian Volcanic Plains; the low-lying landscapes in the coastal plains of the Surf Coast Shire; coastal wetlands adjacent to Corio Bay including the Lake Connewarre complex; and the estuaries and coastal embayments of the Otway coast between Apollo Bay and Princetown. Emphasis was given to sites that had a high probability of ASS being present, and sites that might typically represent a landscape unit.

3.1 Sampled sites

Soils were inspected and sampled at 29 sites with 109 soil samples collected and characterised using morphological descriptors and physical properties such as colour, consistency, structure and texture. Eighty-five samples were selected for basic laboratory analyses such as soil pH, EC (1:5 soil: water) and peroxide pH. Fifty-nine samples selected for detailed analyses such as:

⇒ Detailed ASS analyses such as chromium reducible S, carbonate content and Acid-Base Accounting;

⇒ Geochemical analyses using X-ray fluorescence spectroscopy (XRF).

Soil samples have been briefly described and photographed (Appendix B). Morphological descriptions of diagnostic soil materials and horizons collected from the soil test pits and cores were conducted according to the Australian Soil and Land Survey Field Handbook (McDonald *et al*., 1990). Sampling points are shown in Figure 1 and Appendix A.

Sampling sites were varied across the Western Plains and Southern Uplands. The soil – landform unit (SLU) of each sampling sites was identified using the Corangamite Land Resource Assessment (Robinson *et al*., 2004), and is listed overpage.

Sampling points are shown in Figure 1 and on the Corangamite soil - landform unit maps (Appendix A).

Southern Uplands

Dissected low hills

Alluvial terraces and floodplains associated with Dissected low hills of the Southern Uplands

SLU 96 Floodplain – Barham River (Apollo Bay), Aire River and Princetown Swamp (Gellibrand River) COR25–29

Western Plains

Volcanic plains

Alluvium, terraces, floodplains, swamps and lunettes of the Volcanic Western Plains

SLU 146 Rolling lunettes – Lake Gnarpurt COR3

SLU 153 Gently undulating plains with swamps, lakes and lunettes – Lake Gnarpurt, Lake Corangamite – Cundare Barrage COR2,4–7

SLU 156 Swamps and depressions – Derrinallum COR1

Sedimentary Plains

Plains, rises and low hills of the Sedimentary Western Plains

SLU 190 Undulating plains and terraces (Merrigig Ck.) COR9

Alluvium, alluvial terraces, floodplains and coastal plains of the Sedimentary Western Plains

SLU 194 Near-level plains COR18–20

SLU 199 Dunefield; undulating plains and rises (Point Lonsdale) COR21, 22

SLU 200 Swamps and depressions (Moolap Sunklands L Connewarre) COR8, 10–14

SLU 205 Wetlands of Geelong City COR15–17, 23, 24

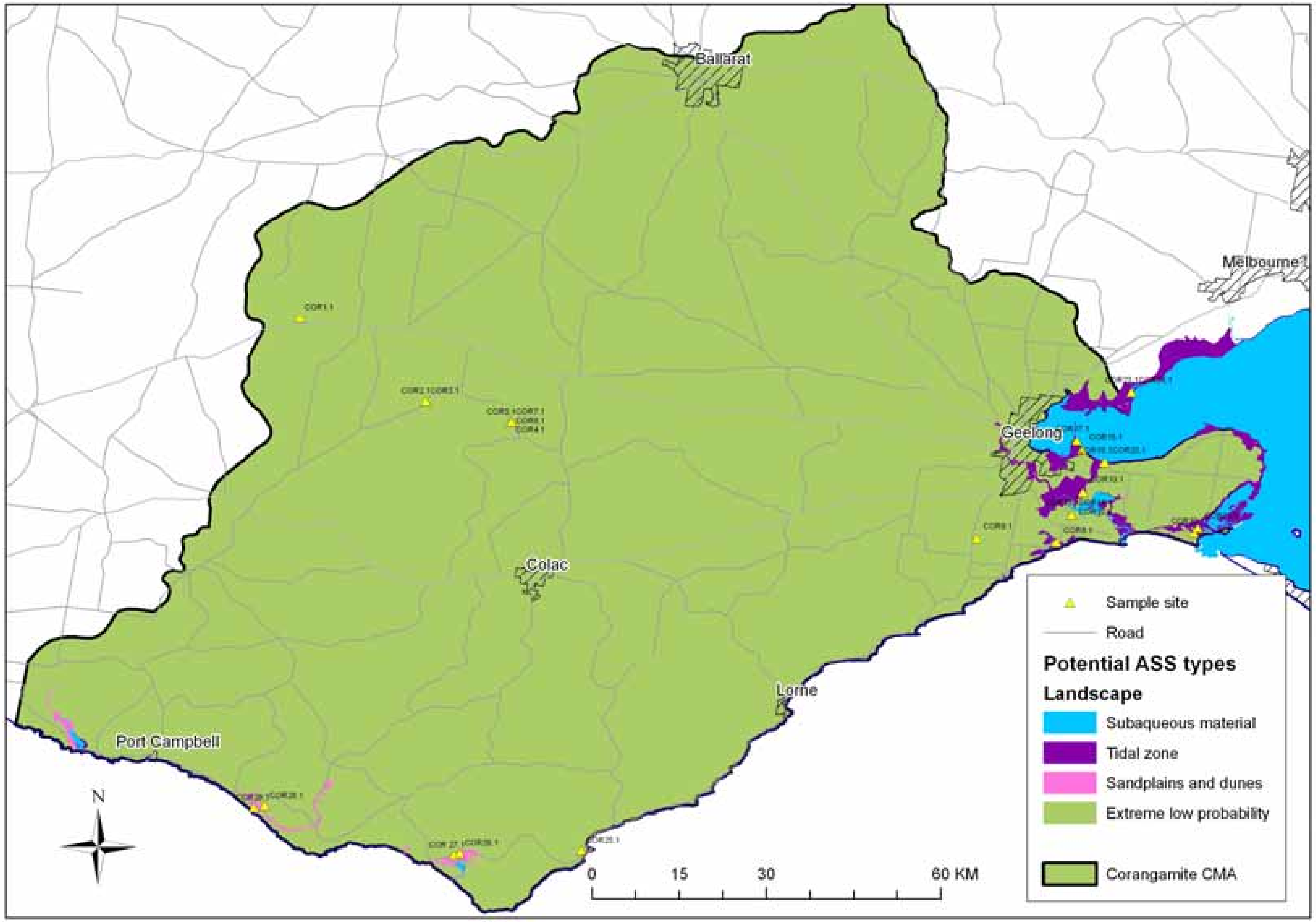

Figure 1: Sampling site locations

4 Sample preparation and laboratory methods

Samples representing the major soil horizons were chosen for selected laboratory analyses. Soil samples were collected in plastic bags and screw top jars, cooled on ice and transported to the CSIRO Laboratories. They were then either frozen prior to freeze drying or rapidly dried at 80 °C in a fan forced oven.

A detailed flow chart for sample collection and preparation for laboratory analysis is shown Figure 2. The laboratory methods used are summarised below and results of these analyses are presented in the Appendix C.

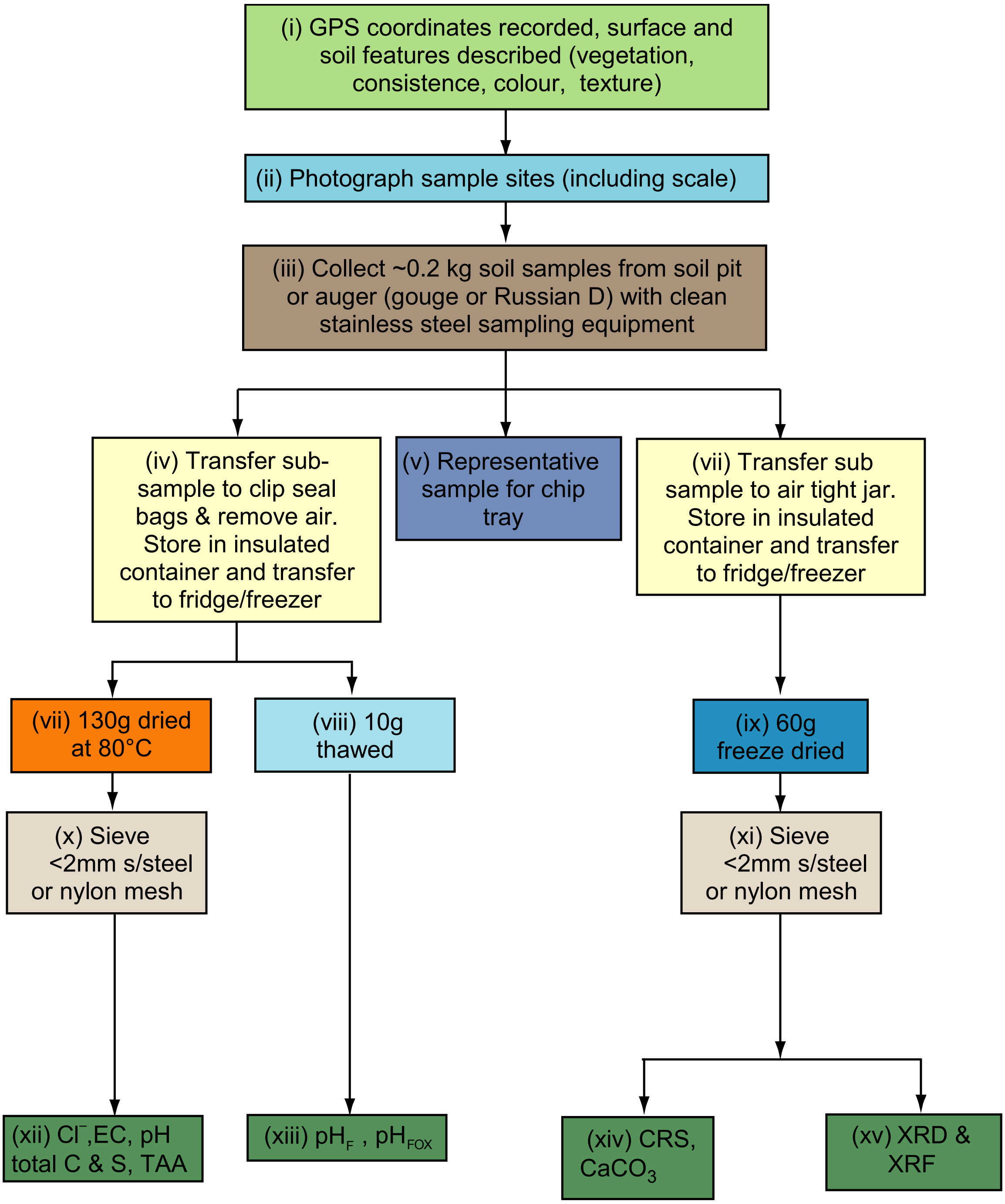

Figure 2: Flowchart for sample collection, preparation and analysis.

4.1.1 Laboratory treatment and analyses

Dried samples were crushed and passed through a 2 mm sieve. Material greater than 2 mm was inspected (mostly coarse organic matter and shell), and proportions recorded. The following analyses were performed using the standard methods of the Analytical Chemistry Unit, CSIRO Land and Water, Canberra and Adelaide:

- ⇒ pH and EC (using 1:5 soil: water extracts): 85 samples;
- ⇒ Calcium carbonate equivalent: 59 samples; and
- ⇒ XRF: 81 samples.

Fifty-nine samples were analysed for chromium reducible sulfur at the Environmental Analysis Laboratory, Southern Cross University, Lismore.

4.1.2 Soil analysis methods

Sample preparation and moisture: Soil samples were frozen, then freeze dried, crushed and sieved through a 2 mm sieve to prepare dry, <2 mm samples for further analysis. This material was then sub-sampled further and hand ground in a ring mill in preparation for chromium reducible sulfur determination. The moisture content was calculated from the measured weight loss on freeze drying the weighed, representative sub-sample.

Electrical conductivity ($EC_{1:5}$): A 4 g sub-sample was placed in a screw cap container, 20 mL of water was added and the suspension shaken for one hour (1:5 soil: water ratio). The electrical conductivity was measured after calibrating the conductivity meter using 0.1M KCl (12.9 dS m^{-1}; Method 2B1; Rayment and Higginson, 1992).

Soil acidity ($pH_{1:5}$): The pH meter was calibrated using pH 7.00 and pH 9.00 buffers. The pH was measured on the same suspension as used for EC (Method 4A1; Rayment and Higginson, 1992).

Calcium carbonate equivalent: Sub-samples (1 to 2 g) of soil and pure calcium carbonate were analysed by adding HCl and measuring CO_2 gas pressure in a glass vessel using a pressure transducer following a slightly modified method of Sherrod *et al*. (2002). Results for inorganic carbon are expressed as calcium carbonate equivalent.

4.1.3 Geochemical analysis

The samples were analysed by X-ray fluorescence spectrometry (XRF) at CSIRO for: (i) major elements and trace elements on fused borate glass discs. These results are presented in Appendix C4.

4.1.4 Chromium reducible sulfur

Methods for analysing soil samples to assess acid generation potential (AGP) are given in Ahern *et al.* (2004), which includes the chromium reducible sulfur (CRS or SCr) (Method Code 22B) and its conversion to AGP. The chromium reducible sulfur method measures the total reduced inorganic sulfur (RIS) species in the sample such as pyrite, mackinawite and greigite. The term RIS is commonly used in marine chemistry, and is now being widely adopted by acid sulfate soil researchers as it better describes the varied mixture of reduced inorganic sulfur species responsible for acid generation.

4.1.5 Net acid generating potential (NAGP)

Net acid generating potential (NAGP) was calculated by subtracting the acid neutralising capacity (ANC) from the AGP. The ANC was calculated as the calcium carbonate equivalent (Ahern *et al*., 2004). A positive value for NAGP indicates acid generating potential and the potential for formation of an ASS, while a negative value indicates an excess of neutralising capacity over acidity, with little likelihood of ASS formation.

5 Results

5.1 Observations of soil profiles

The borehole and test pit locations soil profile logs and images of soil samples are shown in Appendix B.

5.2 Morphology and laboratory analysis

5.2.1 Field description and morphology

In all of the soil profiles, distinct layers were demarcated, described and summarised classified according to the Australian Soil Classification System (Isbell, 1996) (Table 1 and Appendix B). Soil colour, structure, texture and consistency are the most useful properties for soil identification and appraisal. Soil colour, structure and consistency provide practical indicators of soil redox status and salinity/sodicity and this relates directly to soil aeration and organic matter content.

5.2.2 Soil pH and electrical conductivity (EC) in 1:5 soil: water extract

The pH values of the soil horizons of inland samples sampled were alkaline (pH>7.4) and ranged from 7.4 to 8.7. The highest pH values were found in soil horizons at Cundare Barrage associated with either freshwater snail shells or salt efflorescences. For coastal sites, pH values covered a wide range from acid (pH<5.5), circumneutral (5.5<pH<7.4) to alkaline (ph>7.4). The lowest pH values were from the Otway coast. The Aire River floodplain and Princetown Swamp sites had horizons with acid pH values. The lowest pH was 3.9 from 70–100 cm (COR28) in the Princetown Swamp and the highest in this region was 6.6 at 40–90 cm in the bank of the Barham River at Apollo Bay (COR25). Two sites at Point Lonsdale were alkaline (pH range 8.6 to 9.9) and were associated with “shell grit” layers. The other coastal soils sampled in the Geelong area and Thompson River estuary had a pH range from 6.2 to 9.1 with higher values associated with shell layers.

For coastal sites, EC values ranged from 0.19 dS m^{-1} in a sample from the bank of the Aire River (COR26) to 108 dS m^{-1} in the surface of the samphire wetland (COR15) at Point Henry. In the inland sites, EC values ranged from 2.0 dS m^{-1} at Derrinallum (COR1) to 27 dS m^{-1} in dry channel sediments at Cundare Barrage (COR4).

Detailed results for pH and EC are presented in Appendix C1.

5.2.3 Soil pH in hydrogen peroxide (H_2O_2) – pH_{FOX}

The pH of a sample after reaction with hydrogen peroxide is a qualitative indication of the likelihood that a soil material or sediment has the potential to form sulfuric material or an acid sulfate soil when exposed to the atmosphere (e.g. when excavated). The hydrogen peroxide reacts with sulfides to produce sulfuric acid. Sulfuric acid in turn reacts with neutralising agents in the sample, such as carbonates and clay minerals. The final pH can then be interpreted to qualitatively assess soil or sediment materials. The results of this assessment are shown in Appendix C1.

The hydrogen peroxide test indicates that other than Merrigig Creek, the inland soils sampled have a large excess of neutralising capacity and although they may contain reduced inorganic sulfur compounds are benign in regards to acidification risk. Some coastal soils have horizons with sulfidic material which are likely to become sulfuric if disturbed, but other horizons in the profile have excess neutralising capacity. In contrast, on the Otway Coast all soils examined show a positive reaction to the peroxide and are likely to form sulfuric horizons and an acid profile if disturbed, these are:

⇒ Apollo Bay, Barham R bank COR 25 (2 – 15cm and 90–140 cm) with pH_{FOX} values of 3.0 and <2.7;

⇒ Aire R bank COR 26 (120–150 cm) with a pH_{FOX} value of 1.4 and Aire R floodplain (COR 27) with pH_{FOX} values of <2.5 to 90cm; and

⇒ Princetown Swamp COR 28 (15 – 100 cm) with pH_{FOX} values of <2.3 and Princetown Swamp estuary boardwalk COR 29 (100–200 cm) with a pH_{FOX} value of 1.2.

5.3 Sulfur

5.3.1 Total sulfur

In sediments, total sulfur is an inexpensive, convenient measure to screen samples for acid sulfate soil potential. However this analysis estimates the **maximum** potential environmental risk, so that when a trigger value is exceeded, more detailed analysis is required. Seventy-eight samples were analysed for total sulfur using XRF analysis.

5.3.1.1 Investigation results for total S

Total sulfur concentrations in inland samples ranged form 0.42 % at Merrigig Creek (COR9) to 6.3 % on the Lake Corangamite side of the Cundare Barrage channel (COR7). In coastal soils values ranged from 0.10% in the constructed wetland at Point Henry (COR16) to 68% in the surface crust of a profile from the Point Lonsdale area (COR21). When the proportion of reduced to total sulfur is examined this varies widely from 0.5 to 38% in inland soils and 0.3 to 70% in coastal soils.

5.3.2 Chromium reducible sulfur

Sixty-three samples were analysed for reduced inorganic sulfur using the chromium reduction method. Directly measuring the amount of reduced inorganic sulfur (RIS) in a sample using the chromium reduction method has become the accepted standard for further investigation. Chromium reducible sulfur (commonly written as either CRS or S_{Cr}) can be directly equated to the acid generating potential (AGP) of a soil or sediment. The difference between reduced inorganic sulfur and total sulfur is the quantity of sulfate plus organic sulfur in the sample. Further analysis is required to separate the individual contribution of these components, for example to assess the potential for noxious odour generation. For coastal ASS, the action criteria for the preparation of an ASS management plan have been set (Table 1; Dear *et al*., 2002).

Table 1: Criteria for triggering the need for an ASS management plan based on texture range, chromium reducible sulfur concentration and amount of material disturbed.

Texture range	S_{Cr} (%S)	
	<1000 t disturbed	>1000 t disturbed
Coarse: Sands to loamy sands	0.03	0.03
Medium: Sandy loams to light clays	0.06	0.03
Fine: Medium to heavy clays	0.1	0.03

5.3.2.1 Investigation results for S_{Cr}

Chromium reducible sulfur concentrations in the inland samples, ranged from <0.005% at 60–70 cm in Lake Gnarpurt (COR2) to 0.43% at 3–10 cm in the channel on the Lake Corangamite side of the Cundare Barrage (COR7). All samples collected at the inland sites had measurable chromium reducible sulfur, including the surface sediments of Lake Gnarpurt with 0.24% chromium reducible sulfur (COR3). These sediments were forming lunettes around the lake and were being suspended by the strong winds experienced on the day of sampling. At least one soil profile in all areas visited had a horizon with CRS ≥ 0.03%, the trigger value for further investigation when >1000 t of material is to be disturbed and ≥ 0.1% the trigger value for a medium to heavy clay where <1000 t is to be disturbed (Table 1).

At the coastal sites, CRS concentrations ranged from <0.005% to 7.6%. The constructed wetland adjacent to the Alcoa plant at Point Henry had the lowest amount of reduced sulfur in the profile ranging from 0.01–0.03%. The highest value of 7.6% was found in the profile sampled at Princetown Swamp boardwalk at 100–200 cm.

5.4 Carbon

5.4.1 Total carbon

For inland samples total carbon ranged from 1.2 to 11%. The lowest value was from 40–70 cm in Lake Gnarpurt and the highest value from the soil surface on the inland side of the Cundare barrage channel. At the coastal sites total carbon concentrations ranged from 0.10 to 23%, with the higher values associated with shell rich horizons.

5.4.2 Organic carbon

For inland samples total carbon ranged from <0.2 to 6.1%. The lowest value was from 40–70cm in Lake Gnarpurt and the highest value from the soil surface on the inland side of the Cundare barrage channel.

Organic carbon in coastal sites varies from below the detection limit to 23% in the seagrass rich horizon of COR19. As expected, organic carbon concentrations were uniformly high in these horizons at the Corio Bay sites. Organic carbon concentrations were also high ~10% on the Otway coast at the Aire River and Princetown Swamp.

5.4.3 Carbonate

Carbonate minerals in a soil are a component of its acid neutralising capacity (ANC). In the coastal environment much of the carbonate is in the form of shell material which can become unreactive when acidic waters result in the shell fragments becoming coated with iron and/or gypsum. Detailed discussion of precautions and factors to be used when using carbonate values as a measure of ANC can be found in manuals and technical documents published for the assessment of coastal acid sulfate soils (e.g. Dear *et al*., 2002).

5.4.3.1 Investigation results for carbonate content

Eighty soil samples were analysed for carbonate content (expressed as % $CaCO_3$ equivalent). In inland soils, the carbonate concentration varied from 0.10% from 15–50 cm at Merrigig Creek (COR9) to 39% at 0–1 cm in peds from the channel upstream of the Cundare Barrage (COR4). In coastal soils, the natural tidal sediments had high carbonate contents often >20% $CaCO_3$ associated with shelly horizons. The range for coastal areas was from 0.02% at 100–200 cm in Princetown swamp (COR29) to 64 % from 60–75 cm at Avalon (COR24).

5.5 Net acid generating potential (NAGP)

NAGP is calculated by subtracting the acid neutralising capacity (ANC) from the (AGP). A positive value indicates an excess of acid and the likelihood of sulfuric materials (or an actual acid sulfate soil material) forming in the soil when it is disturbed and oxidised. ANC is assumed equal to the $CaCO_3$ content and AGP derived from the %CRS where 1 mole of reduced inorganic sulfur yields 2 moles of acidity so that expressed as %$CaCO_3$ equivalents AGP. To convert from %S_{Cr} to AGP expressed as %$CaCO_3$ equivalent, multiply the value for chromium reducible sulfur by 3.12. Note, when determining liming requirements from %S_{Cr}, a safety factor of 1.5 is usually included along with factors for the effective neutralising capacity of the neutralising material such as purity and fineness (particle size).

5.5.1.1 Investigation results for NAGP

Thirteen sampling sites had soil horizons that gave a positive NAGP result. If disturbed sulfuric material could form in these horizons. Ten sampling sites had either a surface horizon that was could become sulfuric or had net profile acidity. *Note; the NAPG values listed here have not had a safety or fineness factor applied.*

5.5.1.2 Comparison of field peroxide test with NAGP

The peroxide test reflects reactivity of neutralising materials in the soil over a short (1 hour) time period. NAGP reflects the measured chemical composition and does not take into account reactivity and kinetics. That is, while gross composition indicates acid generated “is likely to be” neutralised, carbonate reactivity may play a role.

There were 26 cases where pH_{FOX} was measured and NAGP calculated. In 21 of these 26 cases a positive NAGP was consistent with a pH_{FOX} of at least less than 5.0. (A pH value of 4–5 is considered inconclusive when interpreting pH_{FOX} values.) In two cases both in the one profile (COR8) the pH_{FOX} was 3.4 and 2.5 with a negative NAGP this is likely caused by unreactive shell contributing to the ANC value. In three instances a positive NAGP occurred but when pH_{FOX} was measured pH values were >5. In these cases the reduced sulfur may be present as framboidal pyrite occluded by resistant organic matter so that in the <1 h period of the pH_{FOX} test this was unreactive.

The incubation test (Soil Survey Staff 2003) could be used to better evaluate the self-neutralising efficiency of ASS; however this test takes 8 weeks to produce a result and is generally unsuitable for making operational decisions for engineering works.

5.6 Metals

Results for trace metals and metalloids by XRF are given in Appendix C4. The main element of interest is arsenic, which was present in concentrations above the lower ANZECC interim sediment quality guideline value of 20 mg kg^{-1} and at times above the upper guideline value of 70 mg kg^{-1} and the NEPC values for the protection of health of 100 mg kg^{-1} for soil in domestic gardens and 200 mg kg^{-1} in public recreation areas (ANZECC & ARMCANZ, 2000; Imray and Langley, 1999). There is no evidence that these concentrations are not the natural background as concentrations in excess of 20 mg kg^{-1} are widespread. The range in arsenic concentrations in basalt has been reported as <1 to 113 mg kg^{-1} arsenic (Smith et al., 2003). This is emphasised by the widespread occurrence of arsenic concentrations above 20 mg kg^{-1} at all the locations we sampled other than the Barham River (Apollo Bay) and Aire River on the Otway Coast. It should also be noted, that these are total arsenic concentrations and further testing is required to determine their potential bioavailability. Nickel also occurs above either the upper or lower ISQG values in all profiles analysed and chromium above the lower ISQG value at 14 sites. Zinc above the upper ISQG concentration was found at one site (COR15).

5.7 Mineralogy

The sample mineralogy is summarised in Table 2. The majority of samples were dominated by quartz with some samples having halite or calcite as a co-dominant mineral. Consistent with the RIS analyses, pyrite was identified as a trace (<5%) mineral in a number of samples.

Table 2: Summary table of sample mineralogy.

Sample ID	Quartz	Na-Feldspar	K-feldspar	Calcite	Mg-Calcite	Aragonite	Mica/ Illite	Smectite	Kaolin	Halite	Dolomite/ Ankerite	Gypsum	Pyrite	Others
COR1.1	D	M	M		M	T	M	M	T					
COR1.2	D	T	T		M	T	SD	?M	T					
COR2.3	D	T	T		T		T	?T		T	T			
COR2.4	D	T	T	T			T	?T		T	T			
COR3.1	SD	T	T		T		D	?M	T	T	T	M	T	
COR4.1	D	T	T		?T		M	SD	T	M	T	M		
COR6.1	SD	T		?T		D	M	?M	M					
COR7.2	D	T	T			T	SD	SD	M					
COR8.3	D	T	T				M	SD	M	M				
COR8.4	D	T	T				T	?T	T	M			T	
COR8.5	D	T	T	T		T	T	?T		M			T	
COR8.6	D	T	T	T		T	T	?T	T	M			T	
COR8.7	D	T	T	T		T	T	?T	T	T			T	
COR9.1	D						T	?M	M	T				
COR9.2	D	T	T	T					T	T			T	
COR10.1	D	T	T			?T	M	M	M	T				
COR10.2	D	T	T				M	M	M					
COR10.3	D	T	T				T		T	T				
COR10.4	D	T	T				T	?T	T	T				
COR12.1	D	T		T	M		M	T	M					
COR13.1	D	M	T				T	?T	T					
COR13.2	D	M	T				T		T					
COR13.3	D	T	T			M	T			T		SD		
COR13.4	D	T	T				M	?M	T			T	T	
COR14.1	D	T		T	M	T		?M		SD		M		
COR14.2	D	T	T		T	T	M	?M	T	T			T	
COR15.2	T	T	T	T	M					D				
COR15.3	D	T	T				M		T	SD				
COR15.5	D	T	T	T		M	T		T	M				
COR15.6	CD		T			T	T			CD			T	
COR15.7	D	T	T	T		T				SD			T	
COR15.10	D	T	T	T		T	T	?T	T	T				
COR16.2	D	T	T	T			T	SD	M					
COR16.3	D	T	T	T			M	?M	T					
COR16.4	D	T	T				T	?T	T					
COR16.5	D	T	T				T	?T	T					
COR16.6	D	T	T				T	?T	T		T			
COR17.1	T									SD				D-Mhc; T-Cor; T-Gib
COR17.2	T			T	T					D				SD-Mhc; M-Cor; T-Gib
COR17.3	D	T	T		?T		M	?T	T	SD			T	

Table 2 (continued)

Sample ID	Quartz	Na-Feldspar	K-feldspar	Calcite	Mg-Calcite	Aragonite	Mica/ Illite	Smectite	Kaolin	Halite	Dolomite/ Ankerite	Gypsum	Pyrite	Others
COR18.1	D	T	T				T		T	T				
COR18.2	D	T	T				T			M		T		
COR18.6	D						SD	?M	M				T	
COR20.1	D	T	T	T	T	T				T				
COR21.1	M			M	M			?T	T	D		SD		T-Hex ; M-Bass ; T-Blo ; T-Gla
COR21.2	D	T	T	SD	M	M	T			M		T		
COR21.4	D	T	T	SD	M	T	T			T	T		T	
COR22.4	D	T	T	SD	M	T	T				T		T	
COR22.5	D	T	T	SD	M	T	T			T	T		T	
COR24.1	CD	T	T	T	T		T	?T	T	CD			T	
COR24.2	D	T	T	T		T	T		T	SD			T	
COR28.2	D	T					T	?M	M					
COR28.3	D	T	T				T	?T	T				T	
COR29.3	D	T	T				T	?M	M	T			M	

Notes:

Halite – NaCl
Gypsum – Ca $SO_4.2H_2O$
Bass-Bassanite – Ca SO_4. 0.5 H_2O
Mhc-Monohydrocalcite $CaCO_3.H_2O$
Cor-Corundum Al_2O_3
Gib-Gibbsite AlOOH
Hex-Hexahydrite $MgSO_4.5H_2O$
Blo-Blodite $Na_2Mg(SO_4)_2.4H_2O$
Gla-Glauberite $Na_2Ca(SO_4)_2$

D – Dominant (>60%)
CD – Co-dominant (sum >60%)
SD – Sub-dominant (20-60%)
M – Minor (5-20%)
T –Trace (<5%)
?-Possible

6 Acid sulfate soil management

Coastal development projects such as land reclamation, digging ponds for aquaculture, sand and gravel extraction or dredging for ports and marinas are likely to disturb ASS. Where ASS is disturbed, there is a risk to human heath, local infrastructure and the local environment. However, appropriate management of ASS during development can improve discharge water quality, increase agricultural productivity and protect infrastructure and the environment. Such improvements can generally be achieved by applying low-cost land management strategies based on the identification and avoidance of ASS materials, slowing or stopping the rate and extent of pyrite oxidation, and by retaining existing acidity within the ASS landscape. Acidity and oxidation products that cannot be retained on-site may be managed by other techniques such as acidity barriers or wetlands that intercept and treat contaminated water before it is finally discharged into rivers or estuaries. Selection of management options will depend on the nature and location of the ASS materials, and their position in the landscape. This is why reliable ASS risk maps, at appropriate scales, and characterizing ASS landscapes are so important (see Table 2).

Ranked in order of priority, ASS management follows the list of principles:

1. **Minimise disturbance or drainage of ASS materials;**

   Select an alternative non-ASS site, rather than undertake remediation. If an alternative site is not feasible, design works to minimise the need for excavation or disturbance of ASS materials, by undertaking shallow excavations for drainage measures or foundations, and avoiding lowering groundwater depth that may result in exposure of soils. If ASS materials are close to surface, cover with clean soil to lessen the chance of disturbance and insulate from oxygen.

2. **Prevent oxidation of sulfidic material**

   This may include staging the development project to prevent oxidation of sulfidic material by covering it with an impermeable barrier (e.g. clay), or placing any excavated sulfidic material quickly back into an anaerobic environment, usually below the water table.

3. **Minimise oxidation rate and isolate higher risk materials from exposure**

   This may include covering ASS materials with soil or water to reduce oxygen availability and control the movement of water, or by controlling bacteria or by applying other limiting factors (e.g. alkalinity) through either physical or chemical means to reduce oxidation rate.

4. **Contain and treat acid drainage to minimise risk of significant offsite impacts**

   Typically, this would involve installing a leachate collection and treatment system (e.g. using lime), a permeable reactive barrier (e.g. lime slot) to intercept and neutralize acidic groundwater as it moves thought the soil, or installing an impermeable barrier to locally confine acidic groundwater.

5. **Provide an agent to neutralise acid as it is produced**

   This would involve mixing the ASS material with an excess of lime, or other neutralising agent.

6. **Separate sulfidic materials**

This may include the use of mechanical separation, such as sluicing or hydrocyclone to separate sulfide minerals (e.g. pyrite crystals) from the sulfidic material, followed by treatment (e.g. liming) or disposal of the sulfide minerals in an anaerobic environment.

7. **Hasten oxidation and collection and treatment of acidic leachate**

   This involves spreading the ASS materials in a thin layer on an impervious area to activate rapid oxidation. Rainfall or irrigation leaches the acid and this leachate is collected and treated (e.g. by liming).

8. **Management of stockpiled ASS materials**

   This includes minimising the quantity and duration of storage, minimising the surface area that can be oxidised, covering the soil to minimise rainfall infiltration, stormwater control measures, controlling erosion and collection, and treatment of runoff (leachate).

7 Conclusions

7.1 Key findings

1. No actual acid sulfate soils were identified at either inland or coastal sites. All soil samples tested had a pH > 4 throughout the profile.
2. Potential ASS were identified at 10 sites and these present an ASS hazard ranging from moderate to severe:
   - ⇒ Peroxide pH indicated that, although many of the soil samples contain sulfidic material, most samples have a high acid neutralising capacity. We sampled 17 areas and examined 29 profiles and tested eighty soil samples. The pH_{FOX} of 32 samples in 9 areas fell below 5.0, displaying a tendency to form actual acid sulfate soil if excavated.
   - ⇒ Chromium Reducible Sulfur analysis (S_{Cr}) indicated that all samples from all areas exceeded the acid sulfate soil action criteria proposed by Dear et al., (2002).
   - ⇒ Carbonate content of most soil samples was very high. The highest values (>20%) were in shelly soil horizons in the intertidal areas around Corio Bay.
   - ⇒ Acid Base Accounting identified 25 soil samples with a positive Net Acid Generating Potential (i.e. they do not contain sufficient neutralising material to buffer the acid that they could potentially produce). Apart from Merrigig Creek, these samples were from coastal areas influenced by (Holocene) marine conditions.
3. Compared with ANZECC interim sediment quality standards, elevated trace metal(loid) concentrations were identified at all sites (Cr, Ni and As). In these circumstances the ANZECC Guidelines recommend further investigation to determine background levels and availability of the metals.
4. The Princetown area has concentrations of RIS that are some of the highest recorded in Australia and these represent and extreme ASS risk.

Table 3 lists sites against ASS type, provides the soil classification, assess ASS risk against the infrastructure and environmental elements at risk and provides management recommendations.

Table 3: ASS type, location, classification, risk class and management.

ASS type	SLU	Location	Site No's	Soil Classification	Impacted Element: Aquatic	Impacted Element: Infra-structure	Impacted Element: Land	Risk class	Management
Sulfidic material in inland streams, swamps and depressions	156	Derrinallum	COR1	Aquic Epipedal Sulfidic or Episodic Vertosol	L–M	L	L	L	Do not disturb. Fence to avoid pugging. Protect from erosion.
	190	Merrigig Creek	COR9	Melacic Sulfidic Hypersalic Rudosol	H	H	M	M (areal extent)	
Sulfidic material in inland saline lakes	153, 146	Lake Gnarpurt	COR2, 3	Hypersalic Sulfidic or Gypsic Hydrosol	M	L	M[1]	L–M	Potential for aerial transport of sediment with elevated concentrations of heavy metals and arsenic. Prevent stock from ingesting.
	153	Lake Corangamite, Cundare Barrage channel	COR4, 5, 6, 7	Hypersalic Sulfidic or Gypsic Hydrosol	H	L	L	L–M	
Sulfidic material in coastal swamps and depressions	200	Reedy Lake, Lake Connewarre	COR10, 11	Melacic Sulfidic Redoxic Hydrosol	M	M	M	M	Do not disturb.
	200	Hospital Swamp, Lake Connewarre	COR12, 13, 14	Sulfidic Redoxic Hydrosol	H	M	M	H	
Sulfidic material in upper 1 m in supratidal flats often with samphires	205	Point Henry Salt marsh (Samphire)	COR15, 17	Natric or Sulfidic Calcarosolic Supratidal Hydrosol	L–M	L	L	L	Low risk in-situ. Possible risk if engineering works separate sulfidic material from neutralising material.
	205	Avalon	COR23, 24	Basic Sulfidic or Stratic Rudosol	L–M	L	L	L	
Sulfidic material in upper 1 m in intertidal flats	194	Beach	COR19, 20	Natric Sulfidic Intertidal Hydrosol	M–H?	L	L	M	As above.
Sulfidic material in upper 1 m in estuarine channels and intertidal salt marsh	200	Breamlea	COR8	Hemic Sulfidic Supratidal Hydrosol	H	H	H	H	Do not disturb. Risk during engineering works e.g. road construction. ASS management plan required for sulfidic materials during works.
Sulfidic material in constructed wetlands	205	Point Henry Constructed wetland	COR16	Natric or Sulfidic Calcarosolic Extratidal Hydrosol	L	L	L	L	Possible accumulation of heavy metals in sulfides? Monitoring infrequently.
Sulfidic material buried below fill materials	194	Drysdale ("Marina" embankment)	COR18	Natric Sulfidic Interitdal Hydrosol	H	H	?	H	Keep below water table.
Sulfidic material in sandplains and dunes	199	Point Lonsdale	COR21	Shelly Salic Hydrosol	M	L	L	L–M	Very low risk in-situ. Possible risk if engineering works separate sulfidic material from neutralising material.
	199	Point Lonsdale	COR22	Shelly or Sulfidic Salic Hydrosol	M	L	L	L–M	
Sulfidic material in coastal floodplains	96	Apollo Bay	COR25	Histic-Sulfidic Extratidal Hydrosol	H	H	H	H	High risk, do not disturb. Full ASS management plan and site risk assessment essential if disturbed. Potential problem from pugging and erosion by stock
	96	Aire River	COR26, 27		H	H	H	H	
	96	Princetown Swamp, Gellibrand River	COR28, 29	Histic-Sulfidic Extratidal Hydrosol Histic-Sulfidic Intertidal Hydrosol	VH	VH	VH	VH	Very high risk. Must not be disturbed. Disturbance will result in high environmental OR ASS management costs.

[1] Risk of aerial transport of material rich in RIS and heavy metals is poorly understood.

7.2 Planning and development controls

There is a number of planning and development controls for coastal ASS, which already exist in Victoria. These can be accessed through the Victorian Coastal Council website: http://www.vcc.vic.gov.au/acidsoils.htm as well as links to other ASS information. The 2003 report on coastal acid sulfate soils in Victoria and current coastal ASS maps can be found at: http://www.dpi.vic.gov.au/dpi/vro/vrosite.nsf/pages/soil_acid_sulfate_soils. The Atlas of Australian Acid Sulfate Soils is available through the ASRIS web site: http://www.asris.csiro.au/index_ie.html#.

7.3 Further work

In the Corangamite CMA this study has identified elevated heavy metals (Cr, Ni) and metalloids (As) in soils and sediments. While there is no evidence that these are anything other than background levels, their ecotoxicity and mobility under acid conditions needs to be established. Additionally the fate, hazards and ecotoxicity of aerially transported sediments rich in sulfides and toxic metal(loid)s needs to be investigated. The area around Peterborough remains to be assessed.

Current inland ASS mapping using salinity and waterlogging indices needs to be refined. This will be best done using coverage of all lakes plus riparian wet zones by integrating topographic wetness index (TWI), which defines the riparian wet zones and the sediment deposition zones through Multiresolution Valley Bottom Floor Index (MrVBF) (Gallant and Dowling, 2003).

8 Acknowledgements

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Further information

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APPENDICES

A. SITE LOCATION MAPS

B. SITE AND SAMPLE DETAILS

- **B1 Site details**
- **B2 Photographic index**

C. ANALYTICAL RESULTS

- **C1. pH and EC, peroxide pH**
- **C2. Carbonate**
- **C3. Acid Base Accounting**
- **C4. XRF**
- **C5. XRD**

Appendix A. Site Location Maps

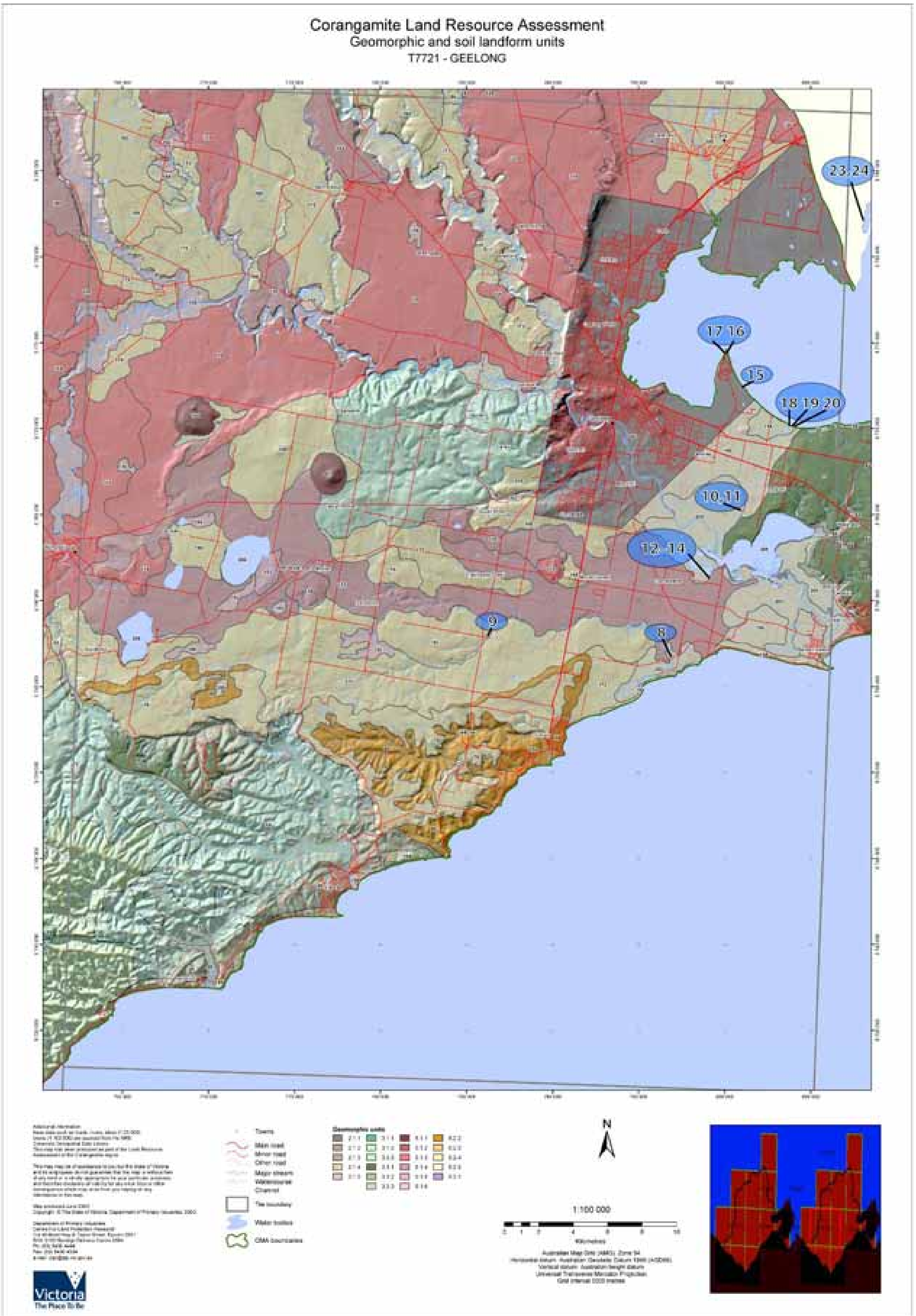


Figure A1 Geelong SLU map with study site locations.

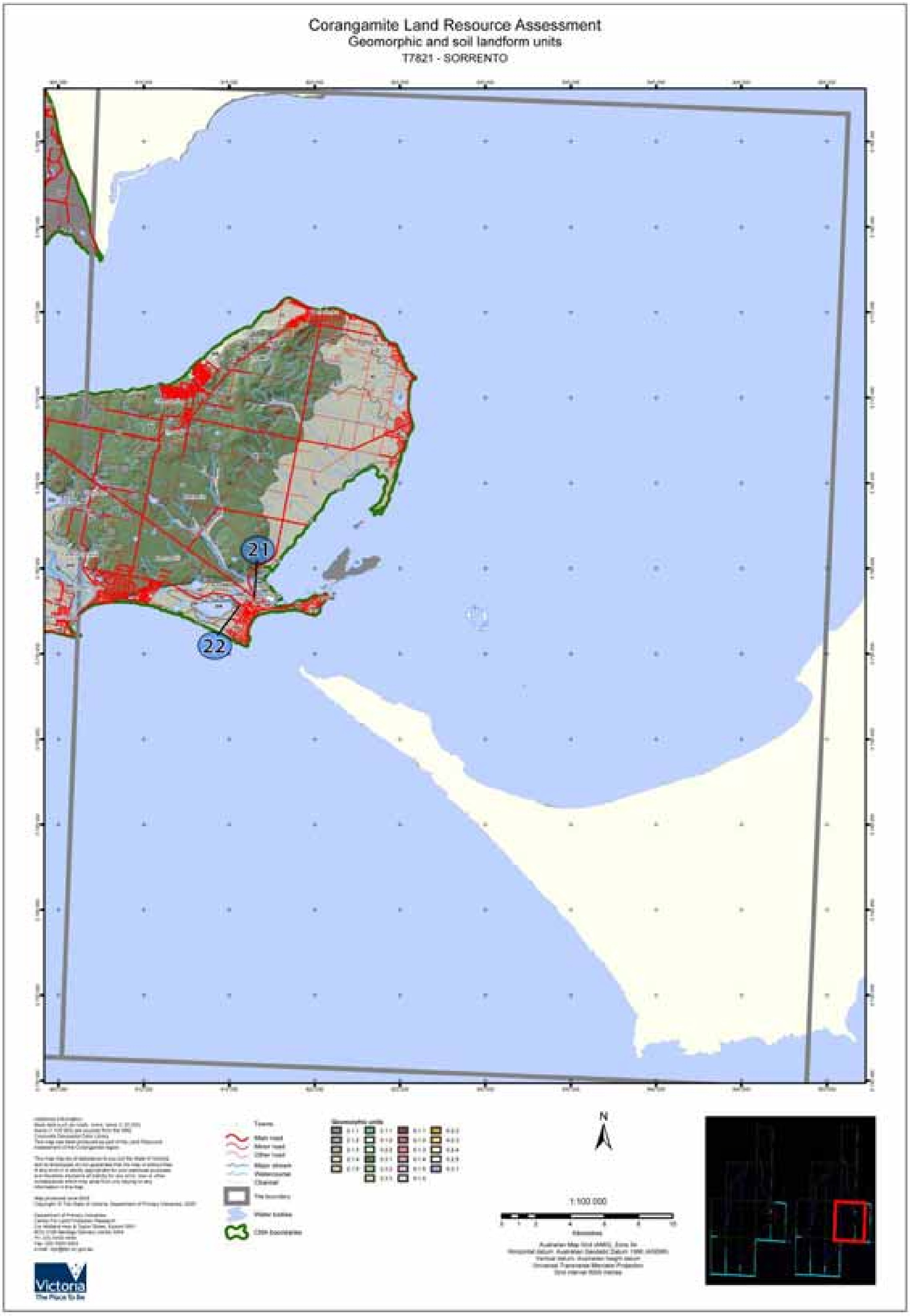


Figure A2 Sorrento SLU map with study site locations.

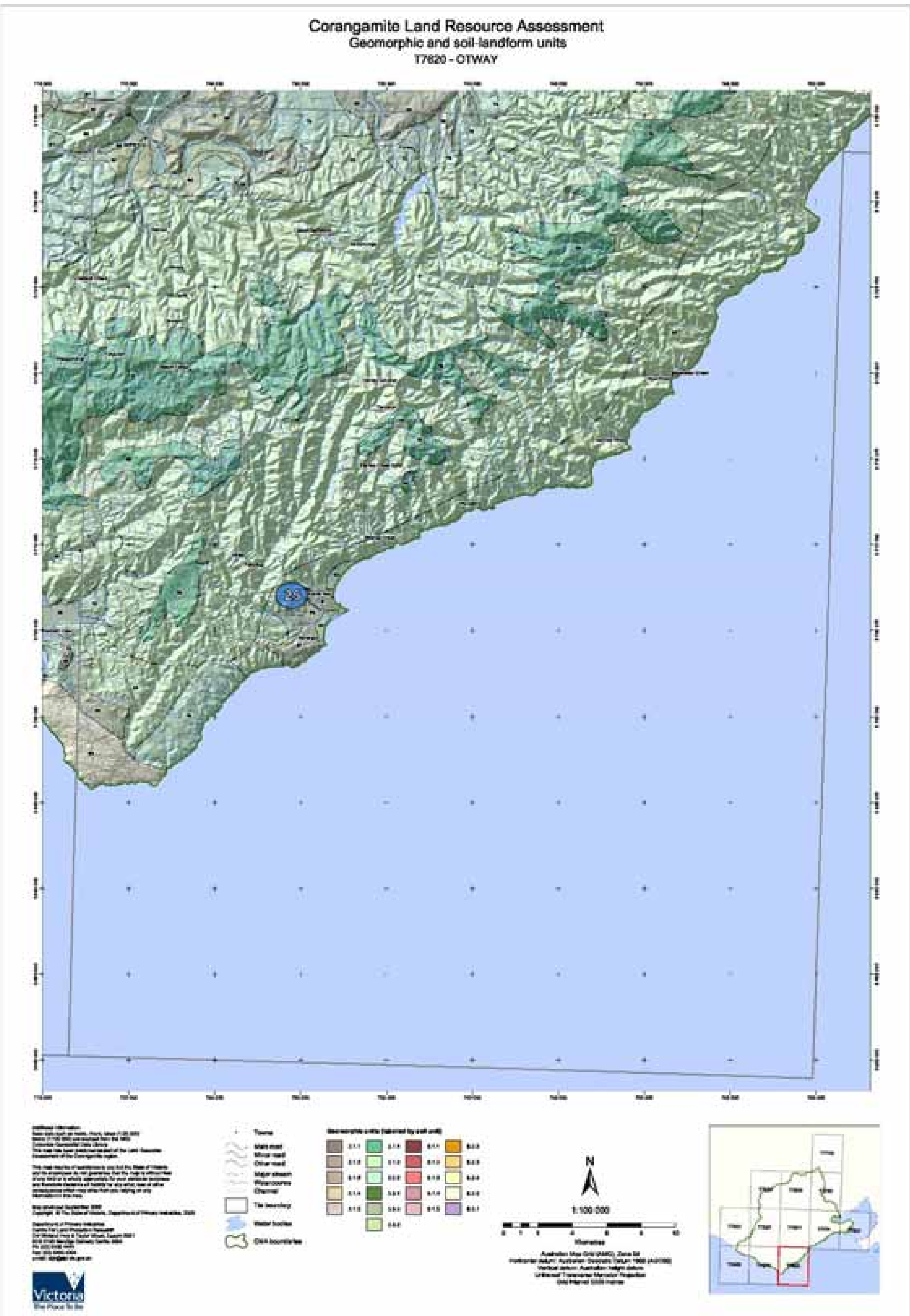


Figure A3 Otway SLU map with study site locations.

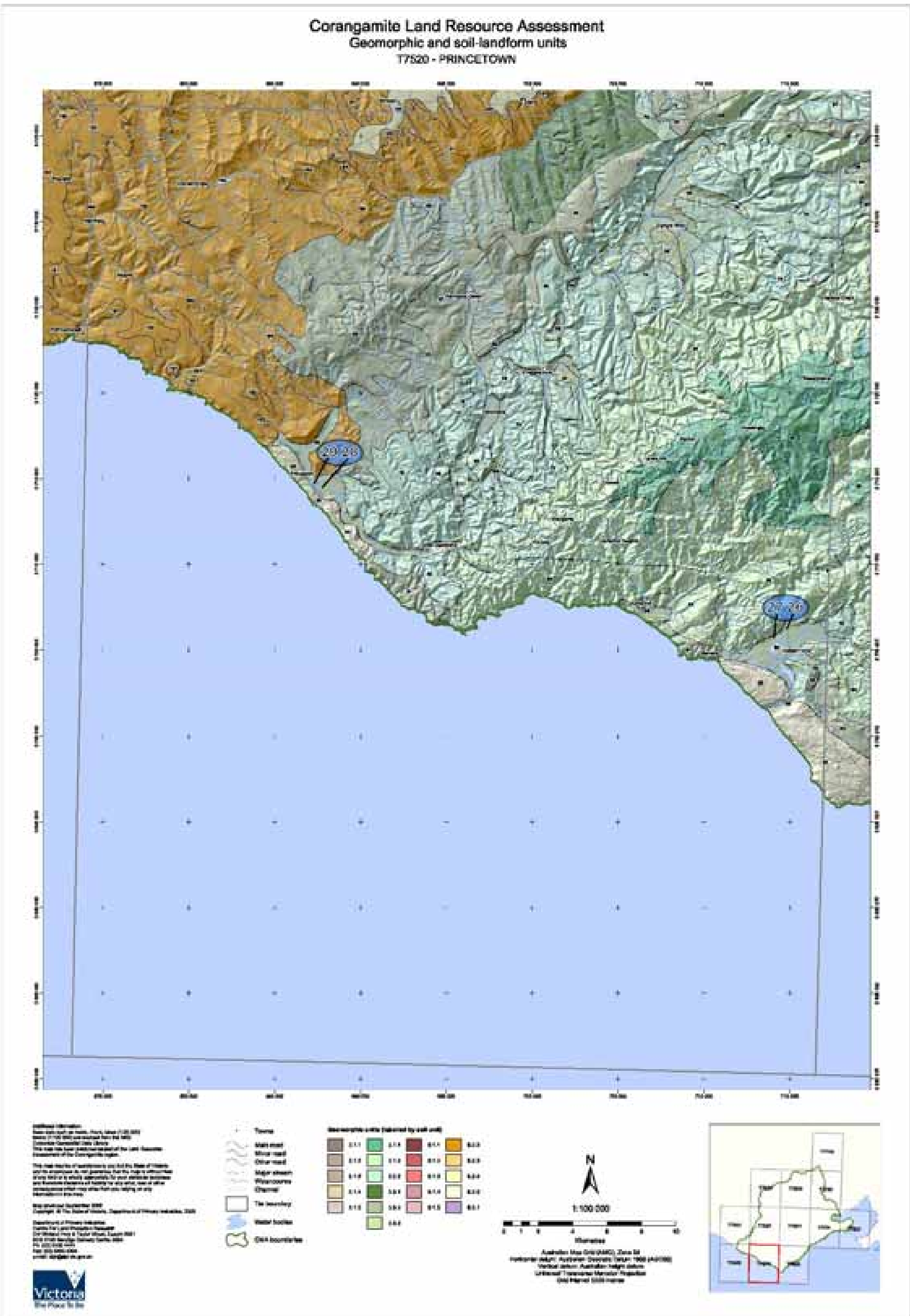


Figure A4 Princetown SLU map with study site locations.

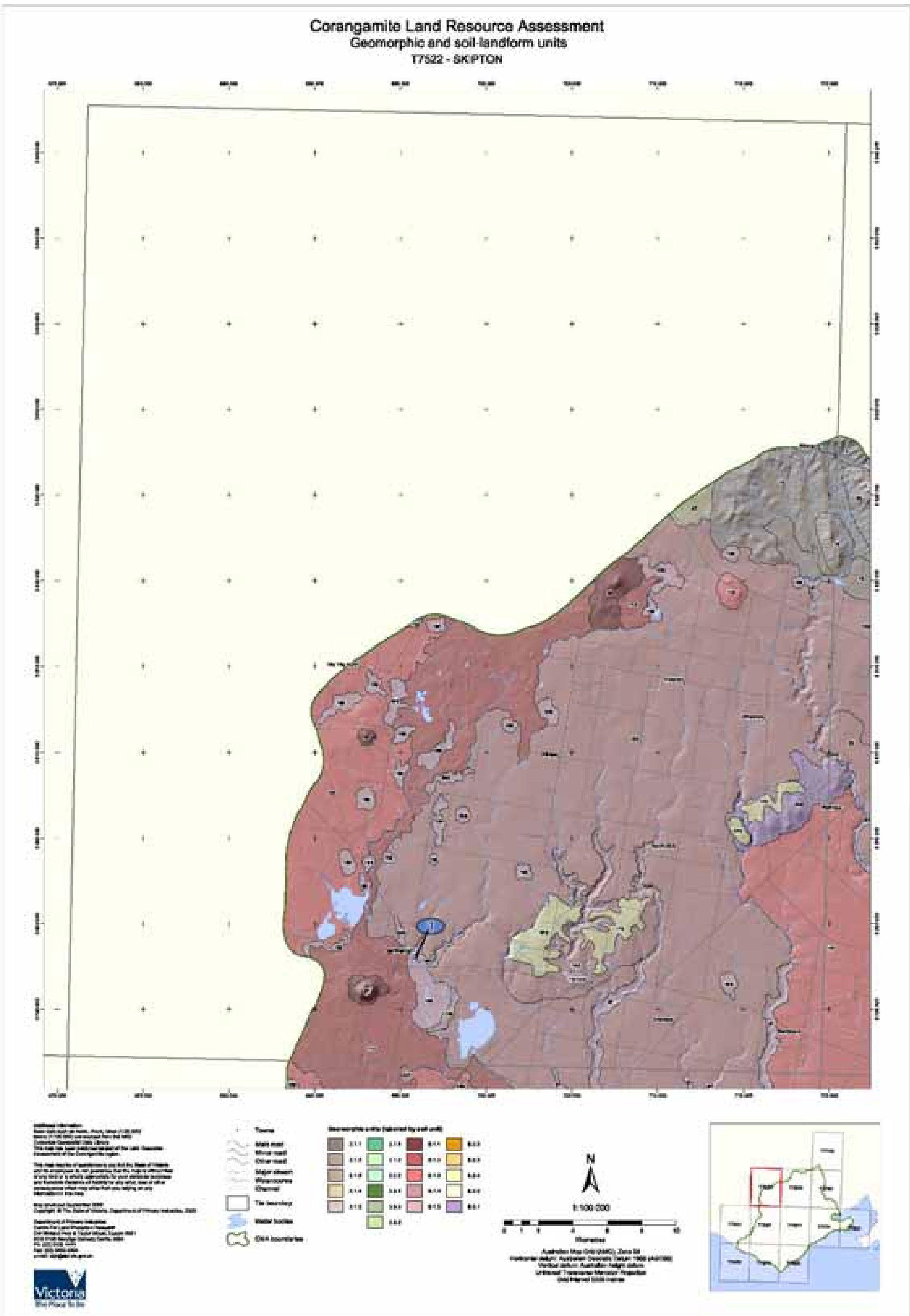


Figure A5 Skipton SLU map with study site locations.

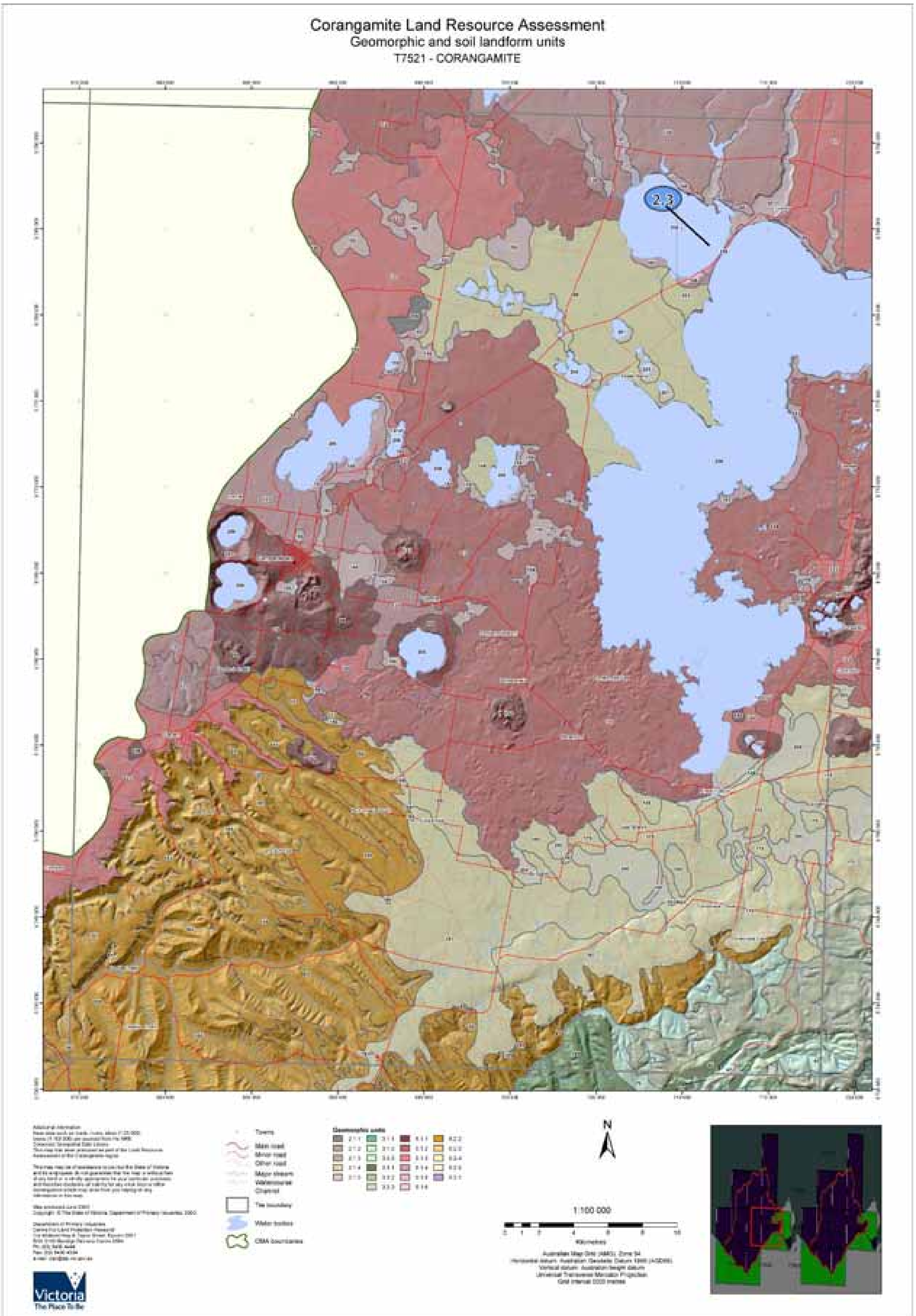


Figure A6 Corangamite SLU map with study site locations.

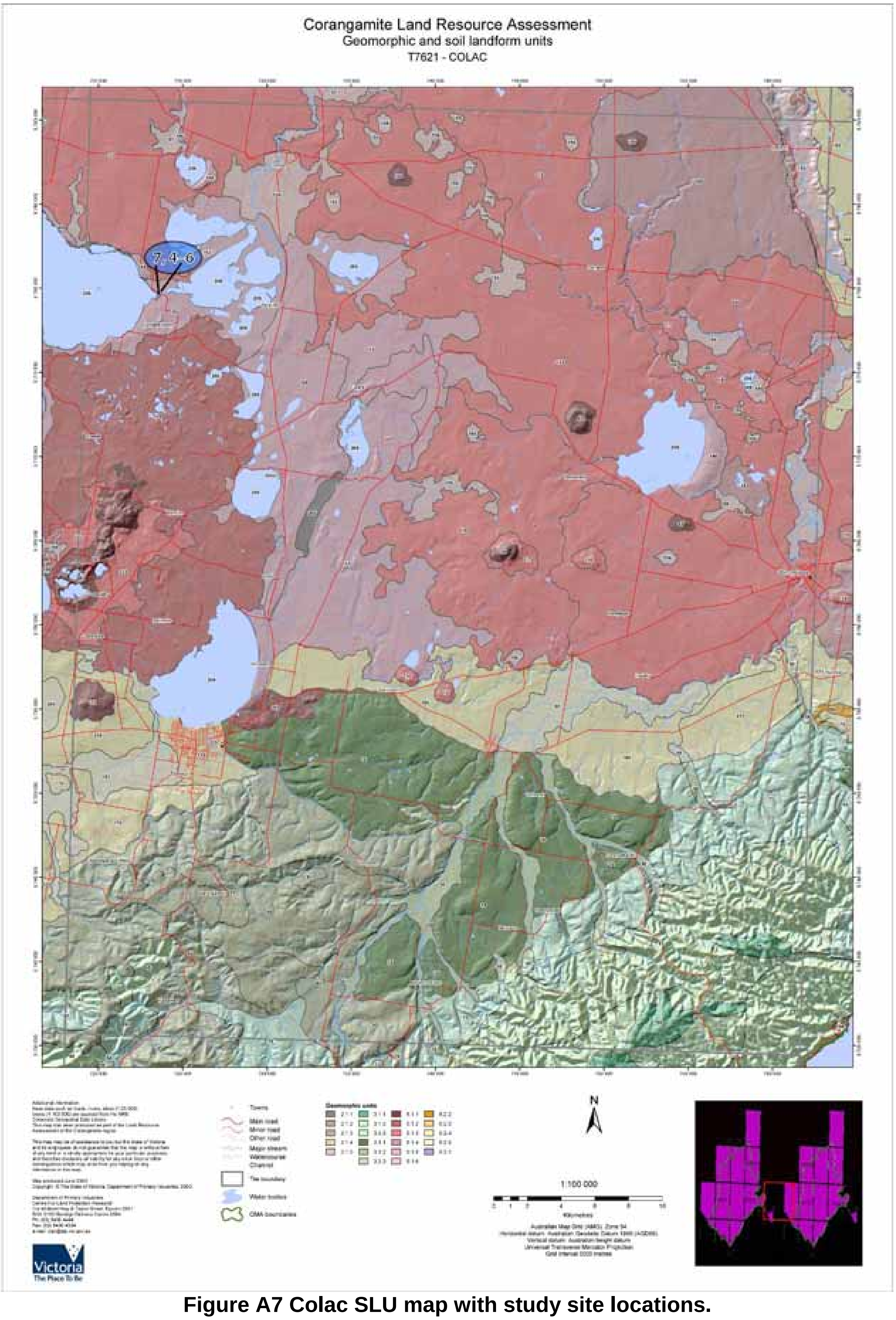


Figure A7 Colac SLU map with study site locations.

Appendix B. Site and Sample Details

B1 Site Details

Projection is UTM unless otherwise indicated.

Sample ID	location 1	location 2	location 3	GPS			site description	sample description	upper depth (cm)	lower depth
				Zone	E	N				
COR1.1	Derrinallum	Mt Elephant	Factory Lane	54	695653	5798466	Gilgai areas of wetland (dry) Only 5% max. of this unit is sulfidic. *Basalt fragments in creek near bridge.		0	5
COR1.2									5	15
COR2.1	Lake Gnarpurt	Westbank	Hopes Rd	54	712364	5783755	Pit 1 Approximately 200m from road * No evidence of ASS in basalt country; ?based on visual (gilgai) + topography			
COR2.2										
COR2.3									40	70
COR2.4									60	70
COR3.1	Lake Gnarpurt			54	712364	5783755	Pit 2 Approximately 300m from road wind blown parna		0	2
COR4.1	Lake Corangamite	Northern section	Cundare Barrage	54	723870	5779846	dry channel gilgai outside wall		0	5
COR4.2									5	10
COR4.3									10	40
COR5.1	Lake Corangamite	Northern section	Cundare Barrage	54	723870	5779846			0	1
COR5.2									1	3
COR5.3										
COR6.1	Lake Corangamite	Northern section	Cundare Barrage	54	723870	5779846	Gilgai with algal mats + carbonate salts?	0-3 S	0	1
COR6.2									1	3
COR7.1	Lake Corangamite	Northern section	Cundare Barrage	54	723870	5779846	pools in channel inside wall mbo, shells mbo, shells	Cracked pattern. Algal mat with greenish clay		
COR7.2								Black sulfidic clay plus shells	3	10
COR8.1	Breamlea	Thompson River bridge	Northern/inland side	55	272296	5759220	sulfidic? strong H_2S smell		0	5
COR8.2				Projection MGA94					5	10
COR8.3									10	30

Sample ID	location 1	location 2	location 3	GPS			site description	sample description	upper depth (cm)	lower depth
				Zone	E	N				
COR8.4									30	60
COR8.5									60	110
COR8.6									110	160
COR8.7								High sulfi?	250	300
COR9.1	Merrigig Creek			55	261472	5759582	black mottles	Bulk sample	0	5
COR9.2									15	50
COR10.1	Lake Connewarre	Reedy Lake	carpark at end of Fitzgerald Road	55	275642	5767904	~30m from carpark interlayered clay-organic sediment ~5cm layers		0	3
COR10.2									3	10
COR10.3									10	30
COR10.4									30	65
COR11.1	Lake Connewarre	Reedy Lake	carpark at end of Fitzgerald Road	55	275642	5767904	~30m from carpark	Black sandy clay loam; high organic matter	0	5
COR11.2								Sandy, NO shells. Grey matrix with yellow mottles	5	50
COR11.3								Yellow clay with grey mottles	50	60
COR11.4								Grey clay with yellow (80%) & some red mottles.	60	75
COR12.1	Lake Connewarre	Hospital Swamp	Hospital Swamp Rd.	55	274207	5764020	end of Hospital Swamp Rd. mbo in 10cm water EC=8.0 dS/m	Algal/water ??? Mat	-5	0
								MBO	0	5
COR13	Lake Connewarre	Hospital Swamp	Hospital Swamp Rd.	55	274207	5764020	end of Hospital Swamp Rd. weak sulfidic mbo organic silty clay	Water	-10	0
COR13.1								Weak MBO + sulfidic	0	5
COR13.2								Organic-rich silty clay	5	10

Sample ID	location 1	location 2	location 3	GPS			site description	sample description	upper depth (cm)	lower depth
				Zone	E	N				
COR13.3							shell no sample black mottles in dark grey matrix light–medium clay	Shell layer (>40% shells) with olive-yellow gleyed silty clay	20	45
COR13.4								Light clay to medium clay. Black mottles in dark grey matrix.	45	70
COR14.1	Lake Connewarre	Hospital Swamp	Hospital Swamp Rd.	55	274207	5764020	drain beside road drain bottom abundant dark black sulfidic mottles in grey clay matrix	Cracked from ???? With RED iron precipitate PLUS algal + salt + CRUST	0	5
COR14.2								Grey matrix with abundant BLACK sulfidic mottles. CLAY MATRIX with few snail shells?	5	10
COR15.1	Point Henry	Windmill Road	Corio Bay tidal samphire wetland	55	275309	5775149	~30m from waterline algal mat mbo strong H_2S hemic seagrass + mangrove fragments increasing clay	Mat: seagrass/algal	-1	0
COR15.2								MBO mud; with abundant fibre	0	1
COR15.3								Brown sapric; weakly sulfidic silty loam	1	5
COR15.4								Shell layers - green-olive clay ??? With brown ????	23	30
COR15.5								Shell layers - green-olive clay ??? With brown ????	30	40
COR15.6								Sulfidic very sapric/hemic	40	50
COR15.7								Sulfidic very sapric/hemic	50	60
COR15.8								Shell + sulfidic	60	75
COR15.9								Shell + sulfidic	75	100
COR15.10								Sandy-loam with sulfidic + few shells	100	135

Sample ID	location 1	location 2	location 3	GPS			site description	sample description	upper depth (cm)	lower depth
				Zone	E	N				
COR16.1	Point Henry	constructed wetland adl Alcoa plant	between Alcoa plant and Corio Bay	55	274490	5776486	adjacent to bird hide closest to Pt Henry jetty water pH 5.3	Thick	-10	0
COR16.2									0	10
COR16.3									10	30
COR16.4									30	60
COR16.5								Blue olive clay weakly sulfidic	60	80
COR16.6								Blue-olive clay	80	100
COR17.1		remnant tidal samphire wetland	seaward of constructed wetland	55	274560	5776562			0	1
COR17.2									1	5
COR17.3									20	30
COR18.1	Drysdale		site of unapproved marina				seaward bank marine horizons (shell & sulfidic material) covered by ~30cm of terrestrial material		0	1
COR18.2									1	15
COR18.3									15	30
COR18.4									80	90
COR18.5									90	120
COR18.6									120	140
COR19.1			local small creek at beach	55	278344	5773003	abundant surface and buried seagrass mattts White film–possibly elemental sulfur. Similar to observations at St Kilda mangrove walk SA very strong H_2S smell		0	5
COR19.2									5	15
COR19.3									15	20
COR20.1			beach	55	278498	5772974	under surface seagrass mat very strong H_2S smell		0	30
COR21.1	Point Lonsdale	Bellarine Highway		55	291329	5762217	~20m in road reserve soil pH 6.5		0	1
COR21.2									1	5
COR21.3								Sulfidic	10	50
COR21.4								Strong sulfidic, sandy	50	100
COR22.1	Point Lonsdale	McMahon's shell grit mine	drain excavation	55	290848	5761374	pH 6.5		-1	0
COR22.2									1	10
COR22.3									20	100
COR22.4									100	150
COR22.5									150	200
COR22.6									200	250

Sample ID	location 1	location 2	location 3	GPS			site description	sample description	upper depth (cm)	lower depth
				Zone	E	N				
COR22.7									250+	
COR23.1	Avalon	Lara	track from Pt Wilson Road	55	281735	5785114	tidal samphire wetland		0	5
COR23.2									5	10
COR23.3									10	25
COR23.4									25	50
COR23.5										
COR23.6										
COR24.1	Avalon	Lara	track from Pt Wilson Road	55	281735	5785114	tidal samphire wetland pool ~ 3cm deep mbo gel consolidated gel		0	5
COR24.2									5	10
COR24.3								Shells + sulfidic	60	75
COR24.4								Green-olive medium clay; no shells	75	80
COR25.1	Apollo Bay	Barham River	river bank at water line	54	731262	5706280		Sandy organic	2	15
COR25.2								Sulfidic sandy ?	40	90
COR25.3								Organic	90	115
COR25.4								Clayey sulfidic	115	140
COR26.1	Aire River	river bank	near shack	54	714913	5706247			1	120
COR26.2									120	150
COR 27.1	Aire River	wetland	GPS coordinate on Great Ocean Road	54	714161	5705938	site ~ 200m SE of coordinate hint of Fe floc, possibly Al floc pH 5.3		0	20
COR 27.2									20	80
COR 27.3									80	90
COR28.1	Princetown Swamp		GPS = 20m in swamp	54	688891	5715023	In swamp edge of reeds	Black abundant roots & root mat; sulfidic	0	15
COR28.2								Very BLACK sulfidic silty clay	15	50
COR28.3								Brown sulfidic silty clay	70	100
COR29.1	Princetown Swamp	Boardwalk-estuary		54	687412	5714722			0	15
COR29.2								Black	20	50
COR29.3								Strong sulfidic, brown colour uniform	100	200

B2 Photographic index



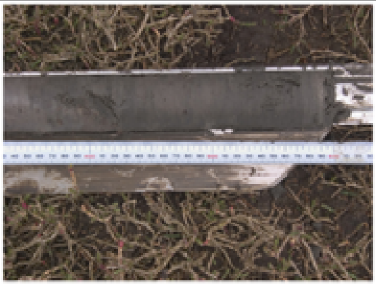
Derrinallum COR1: Aquic Epipedal Sulfidic or Episodic Vertosol

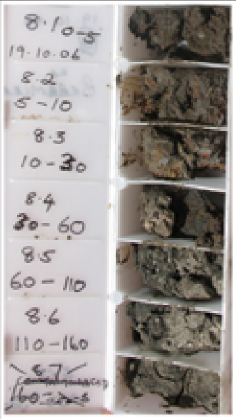



Lake Gnarpurt COR2, 3: Hypersalic Sulfidic or Gypsic Hydrosol



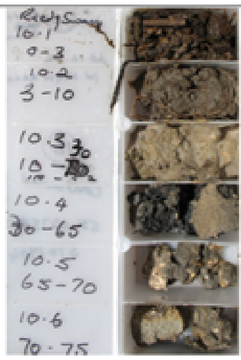
Lake Corangamite, Cundare Barrage channel COR 4–7: Hypersalic Sulfidic or Gypsic Hydrosol





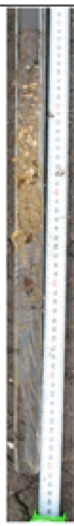
Thompson R at Breamlea COR8: Hemic Sulfidic Supratidal Hydrosol

Merrigig Ck COR9: Melacic Sulfidic Hypersalic Rudosol



Reedy Lake, L Connewarre COR 10, 11: Melacic Sulfidic Redoxic Hydrosol





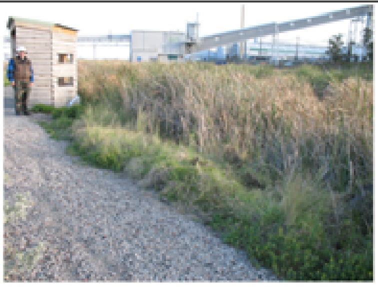
Hospital Swamp L Connewarre COR12, 13: Sulfidic Redoxic Hydrosol



Hospital Swamp drain, L Connewarre COR14: Sulfidic Redoxic Hydrosol



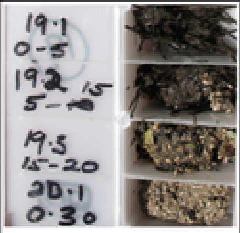
Point Henry saltmarsh COR15: Natric or Sulfidic Calcarosolic Supratidal Hydrosol



Constructed wetland, Point Henry COR16: Natric or Sulfidic Calcarosolic Extratidal Hydrosol

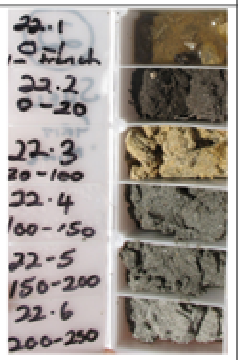
Remnant salt marsh, Point Henry COR17: Natric or Sulfidic Calcarosolic Supratidal Hydrosol

Embankment, unauthorised marina, Drysdale COR 18: Natric Sulfidic Intertidal Hydrosol

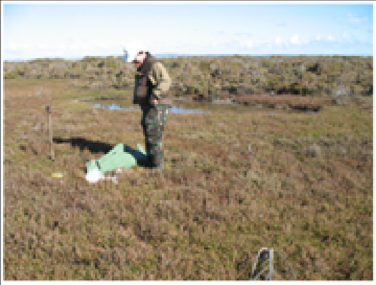


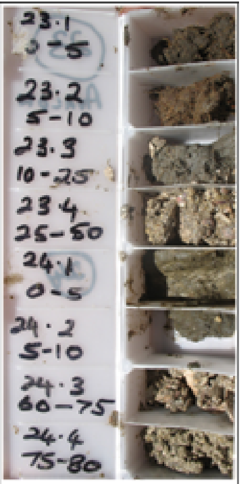
Spring on beach at Drysdale COR19, 20: Natric Sulfidic Intertidal Hydrosol

Point Lonsdale COR21: Shelly Salic Hydrosol



Shell grit mine, Point Lonsdale COR22: Shelly or Sulfidic Salic Hydrosol

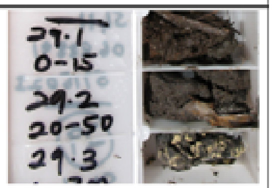




Saltmarsh Avalon COR23, 24: Basic Sulfidic or Stratic Rudosol

Barham R, Apollo Bay COR25: Histic-Sulfidic Extratidal Hydrosol

Aire R and floodplain COR26, 27: Histic-Sulfidic Extratidal Hydrosol

		
Princetown Swamp, Gellibrand R COR28: Histic-Sulfidic Supratidal Hydrosol		
		
Princetown Swamp at estuary, Gellibrand R COR29: Histic-Sulfidic Intertidal Hydrosol		

Appendix C. Analytical Results

C1. Soil pH and EC in 1:5 soil-water extract and Soil pH in H_2O_2

Sample ID	ud	ld	EC dS m^{-1}	Cl mg kg^{-1}	pH	pH_F	pH_{FOX}	React vigor	Interpretation[#]		
	(cm)		water 1:5						ΔpH	pH_{FOX}	
COR1.1	0	5	2.0	2500	7.7	6.9	6.3	1	0.6	>5	Not PASS some AGP
COR1.2	5	15	2.1	2800	7.9	6.9	6.3	1	0.6	>5	
COR2.1	0	10	–	–	–	–	–	–	–	–	
COR2.2	10	40	–	–	–	–	–	–	–	–	
COR2.3	40	70	12	20000	8.6	–	–	–	–	–	
COR2.4	60	70	16	27000	8.6	7.5	6.8	1	0.7	>5	Not PASS some AGP
COR3.1	0	2	18	29000	8.7	7.6	7.4	4	0.2	>5	Not PASS little AGP
COR4.1	0	5	27	53000	8.5	7.6	7.3	4	0.3	>5	Not PASS little AGP
COR4.2	5	10	–	–	–	–	–	–	–	–	
COR4.3	10	40	–	–	–	–	–	–	–	–	
COR5.1	0	1	–	–	–	–	–	–	–	–	
COR5.2	1	3	–	–	–	–	–	–	–	–	
COR5.3			–	–	–	–	–	–	–	–	
COR6.1	0	1	4.9	5500	8.5	8.3	7.5	4	0.8	>5	Not PASS some AGP
COR6.2	1	3	–	–	–		–	–	–	–	
COR7.1	0	3	–		–		–				
COR7.2	3	10	10	6000	7.8	8.5	7.2	1	1.3	>5	Not PASS medium AGP
COR8.1	0	5	–	–	–		–	–	–	–	
COR8.2	5	10	–	–	–		–	–	–	–	
COR8.3	10	30	20	38000	6.2	5.5	4.6	0	0.9	4–5	Inconclusive
COR8.4	30	60	16	13000	6.2	5.8	2.6	1	3.2	<3	Likely PASS
COR8.5	60	110	10	16000	7.7	6.7	5.4	1	1.3	>5	Not PASS medium AGP
COR8.6	110	160	13	21000	7.7	6.9	3.4	4	3.5	3–4	Likely PASS
COR8.7	250	300	9.1	13000	7.6	6.8	2.5	4	4.3	<3	PASS
COR9.1	0	5	5.2	7700	7.4	6.8	4.2	2	2.6	4–5	Likely PASS with high ANC
COR9.2	15	50		3500	–	–	–	–	–	–	
COR10.1	0	3	2.7	3300	6.8	6.2	3.5	3	2.7	3–4	Likely PASS with high ANC
COR10.2	3	10	1.9	2200	6.9	6.4	3.6	1	2.8	3–4	Likely PASS with high ANC
COR10.3	10	30	3.7	1400	8.0	7.0	7.2	4	-0.2	>5	Not PASS no AGP
COR10.4	30	65	4.0	4500	8.0	7.0	5.8	0	1.2	>5	Not PASS some AGP
COR11.1	0	5	–	–	–		–	–	–	–	
COR11.2	5	50	–	–	–		–	–	–	–	
COR11.3	50	60	–	–	–		–	–	–	–	
COR11.4	60	75	–	–	–		–	–	–	–	
COR12.1	0	5	7.1	9400	7.7	7.0	6.1	4	0.9	>5	Not PASS some AGP
COR13.1	0	5	2.1	2600	8.0	6.9	5.2	2	1.7	>5	Not PASS some AGP
COR13.2	5	10	1.4	1600	7.7		–				
COR13.3	20	45	5.3	4300	7.4	7.0	6.4	0	0.6	>5	Not PASS little AGP
COR13.4	45	70	4.0	3200	6.7	7.0	2.1	4	4.9		PASS
COR14.1	0	5	41	76000	8.2	6.6	7.2	4	-0.6	>5	Not PASS no AGP
COR14.2	5	10	11	16000	8.1	7.1	4.3	4	2.8	4–5	Likely PASS with high ANC
COR15.1	-1	0	–	–	–		–				
COR15.2	0	1	108	210000	8.0	6.5	5.9	3	0.6	>5	Not PASS little AGP
COR15.3	1	5	80	140000	6.7	5.6	5.0	1	0.6	>5	Inconclusive
COR15.4	23	30	–		–	7.1	5.8	2	1.3	>5	Not PASS little AGP
COR15.5	30	40	22	49000	9.1		–				
COR15.6	40	50	64	150000	6.8	6.8	5.0	1	1.8	>5	Likely PASS with high ANC (ΔpH)
COR15.7	50	60	59	140000	7.3	6.9	5.0	1	1.9	>5	Likely PASS with high ANC (ΔpH)
COR15.8	60	75	–	–	–	–	–	–	–	–	
COR15.9	75	100	–	–	–	–	–	–	–	–	
COR15.10	100	135	8.1	11000	8.7	7.1	6.1	0	1.0	>5	Not PASS little AGP
COR16.1	-10	0	4.0	4700	5.8	6.1	4.9	1	1.2	4–5	Inconclusive
COR16.2	0	10	0.34	180	7.5	7.1	8.7	4	-1.6	>5	Not PASS, high ANC, Little AGP
COR16.3	10	30	0.37	330	8.0	7.2	9.0	4	-1.8	>5	Not PASS, high ANC, Little AGP
COR16.4	30	60	0.23	89	8.1	6.9	8.1	4	-1.2	>5	Not PASS, high ANC, Little AGP
COR16.5	60	80	0.23	83	8.1	7.0	7.9	4	-0.9	>5	Not PASS, high ANC, Little AGP
COR16.6	80	100	0.28	130	8.1	7.2	8.2	4	-1.0	>5	Not PASS, high ANC, Little AGP

Sample ID	ud	ld	EC	Cl	pH	pH_F	pH	React	Interpretation[#]		
	(cm)		dS m^{-1}	mg kg^{-1}			FOX	vigor	ΔpH	pH FOX	
COR17.1	0	1	37	74000	8.7	7.1	7.0	3	0.1	>5	Not PASS little AGP
COR17.2	1	5	36	70000	8.5	7.4	6.5	2	0.9	>5	Not PASS little AGP
COR17.3	20	30	31	61000	7.6	7.4	4.7	1	2.7	4–5	Inconclusive
COR18.1	0	1	11	18000	7.7	6.5	5.7	1	0.8	>5	Not PASS, little AGP
COR18.2	1	15	2.8	4000	7.9	7.0	5.6	1	1.4	>5	Not PASS, little AGP
COR18.3	15	30	–		–		–	–	–	–	
COR18.4	80	90	8.8	13000	7.5	6.8	5.7	1	1.1	>5	Not PASS, little AGP
COR18.5	90	120	8.7	12000	7.3	6.6	1.9	2	4.7	<3	PASS
COR18.6	120	140	7.7	9700	5.8	6.7	1.7	4	5.0	<3	PASS
COR19.1	0	5	15	31000	7.3	7.2	4.9	1	2.3	4–5	Inconclusive, high ANC (ΔpH)
COR19.2	5	15	38	74000	7.2	6.9	4.4	1	2.5	4–5	Inconclusive, high ANC (ΔpH)
COR19.3	15	20	12	18000	7.9	7.2	6.2	1	1.0	>5	Not PASS, little AGP
COR20.1	0	30	7.3	10000	8.5	7.2	6.2	1	1.0	>5	Not PASS, little AGP
COR21.1	0	1	61	84000	9.6	8.5	6.5	1	2.0	>5	Not PASS, high ANC
COR21.2	1	5	18	31000	8.9	7.6	6.3	2	1.3	>5	Not PASS, little AGP
COR21.3	10	50	6.2	7500	9.5	7.5	6.5	1	1.0	>5	Not PASS, little AGP
COR21.4	50	100	6.1	7500	9.1	7.4	6.2	1	1.2	>5	Not PASS, little AGP
COR22.1	-1	0	25	35000	9.9	8.1	6.4	0	1.7	>5	Not PASS, little AGP
COR22.2	1	10	6.6	8800	8.9	7.5	6.1	2	1.4	>5	Not PASS, little AGP
COR22.3	20	100	1.3	1400	9.0	7.9	6.7	0	1.2	>5	Not PASS, little AGP
COR22.4	100	150	1.7	1900	8.6	7.5	6.2	1	1.3	>5	Not PASS, little AGP
COR22.5	150	200	1.5	1500	8.6	7.5	6.4	2	1.1	>5	Not PASS, little AGP
COR22.6	200	250	1.5	1100	8.6	7.5	6.3	2	1.2	>5	Not PASS, little AGP
COR22.7	250 +		1.5	1400	8.6	7.6	6.3	1	1.3	>5	Not PASS, little AGP
COR23.1	0	5	61	120000	6.9	6.5	5.4	1	1.1	>5	Not PASS, little AGP
COR23.2	5	10	58	120000	7.0	7.0	5.7	2	1.3	>5	Not PASS, little AGP
COR23.3	10	25	19	35000	7.4	7.0	5.8	2	1.2	>5	Not PASS, little AGP
COR23.4	25	50	12	21000	8.4	7.1	6.2	2	0.9	>5	Not PASS, little AGP
COR23.5			–	–	–	–	–	–	–	–	
COR23.6			–	–	–	–	–	–	–	–	
COR24.1	0	5	50	110000	7.7	7.0	6.2	2	0.8	>5	Not PASS, little AGP
COR24.2	5	10	43	89000	7.7	6.9	4.4	2	2.5	4–5	Not PASS, high ANC
COR24.3	60	75	12	20000	8.7	7.5	6.2	1	1.3	>5	Not PASS, little AGP
COR24.4	75	80			–		–	–	–	–	
COR25.1	2	15	0.59	500	6.5	6.1	3.0	1	3.1	3–4	PASS
COR25.2	40	90	0.30	270	6.6	6.1	4.7	2	1.4	4–5	Inconclusive
COR25.3	90	115	0.61	420	6.0	5.8	2.7	2	3.1	<3	PASS
COR25.4	115	140	0.34	360	5.8	5.7	2.4	3	3.3	<3	PASS
COR26.1	1	120	–		–		–	–	–	–	
COR26.2	120	150	0.19	140	5.6	5.3	1.4	1	3.9	<3	PASS
COR 27.1	0	20	2.1	2900	5.1	5.0	1.8	1	3.2	<3	PASS
COR 27.2	20	80	5.7	8200	5.1	5.4	2.1	1	3.3	<3	PASS
COR 27.3	80	90	4.3	6200	5.2	5.2	2.5	1	2.7	<3	PASS
COR28.1	0	15	6.2	8200	5.3	5.4	3.1	1	2.3	3–4	PASS
COR28.2	15	50	4.2	5200	5.5	5.8	2.3	4	3.5	<3	PASS
COR28.3	70	100	2.9	2700	3.9	5.6	1.2	4	4.4	<3	PASS
COR29.1	0	15	13	21000	6.1	7.0	4.3	1	2.7	4–5	Inconclusive but high ΔpH
COR29.2	20	50	8.7	13000	6.5	6.1	4.7	1	1.4	4–5	Inconclusive
COR29.3	100	200	12	14000	4.4	7.0	1.2	4	5.8	<3	PASS

C2. Carbonate content of selected soil samples

Sample ID	upper depth (cm)	lower depth (cm)	Total C %	Carbonate as $\%CaCO_3$	Org C[#] %
COR1.1	0	5	5.9	15	4.1
COR1.2	5	15	5.9	14	4.3
COR2.1	0	10	–	–	–
COR2.2	10	40	–	–	–
COR2.3	40	70	1.2	12	nd
COR2.4	60	70	1.3	13	nd
COR3.1	0	2	2.6	8.7	1.6
COR4.1	0	5	–	8.0	–
COR4.2	5	10	–	–	–
COR4.3	10	40	–	–	–
COR5.1	0	1	–	–	–
COR5.2	1	3	–	–	–
COR5.3			–	–	–
COR6.1	0	1	11	39	6.1
COR6.2	1	3	–	–	–
COR7.1	0	3	–	–	–
COR7.2	3	10	3.7	8.9	2.7
COR8.1	0	5	–	–	–
COR8.2	5	10	–	–	–
COR8.3	10	30	–	0.1	–
COR8.4	30	60	1.4	0.6	1.3
COR8.5	60	110	1.2	4.7	0.65
COR8.6	110	160	1.7	5.0	1.1
COR8.7	250	300	1.4	5.8	0.66
COR9.1	0	5	4.6	0.2	4.6
COR9.2	15	50	1.6	<0.1	1.59
COR10.1	0	75	11	0.1	10
COR10.2	3	10	5.4	0.1	5.4
COR10.3	10	30	0.10	<0.1	0.093
COR10.4	30	65	1.6	0.1	1.6
COR11.1	0	5	–	–	–
COR11.2	5	50	–	–	–
COR11.3	50	60	–	–	–
COR11.4	60	75	–	–	–
COR12.1	-5	0	12	7.0	11
	0	5	3.3	0.4	3.2
COR13	-10	0	2.2	0.1	2.2
COR13.1	0	5	–	15	–
COR13.2	5	10	0.54	0.4	0.49
COR13.3	20	45	–	8.6	–
COR13.4	45	70	2.2	3.1	1.8
COR14.1	0	5	–	–	–
COR14.2	5	10	14	8.6	13
COR15.1	-1	0	11	0.1	11
COR15.2	0	1	–	–	–
COR15.3	1	5	–	27	–
COR15.4	23	30	14	0.9	14
COR15.5	30	40	–	3.5	–
COR15.6	40	50	–	–	–
COR15.7	50	60	–	–	–
COR15.8	60	75	0.61	6.0	nd
COR15.9	75	100	–	0.1	–
COR15.10	100	135	0.78	3.1	0.40
COR16.1	-10	0	0.75	2.1	0.50
COR16.2	0	10	–	0.5	–
COR16.3	10	30	–	0.5	–
COR16.4	30	60	0.43	0.7	0.34
COR16.5	60	80	9.9	24	7.1
COR16.6	80	100	11	23	8.5
COR17.1	0	1	1.2	0.3	1.2
COR17.2	1	5	5.9	0.2	4.1
COR17.3	20	30	5.9	0.1	4.3

[#] nd = not determined

Sample ID	upper depth (cm)	lower depth (cm)	Total C %	Carbonate as $\%CaCO_3$	Org C %
COR18.1	0	1	–	–	–
COR18.2	1	15	13	0.2	13
COR18.3	15	30	–	0.1	–
COR18.4	80	90	0.46	0.1	0.44
COR18.5	90	120	1.5	2.0	1.5
COR18.6	120	140	0.34	1.4	0.33
COR19.1	0	5	19	31	18.9
COR19.2	5	15	23	23	23
COR19.3	15	20	6.9	22	3.3
COR20.1	0	30	3.1	38	0.35
COR21.1	0	1	–	54	–
COR21.2	1	5	–	55	–
COR21.3	10	50	6.0	47	nd
COR21.4	50	100	6.7	26	0.17
COR22.1	-1	0	–	61	–
COR22.2	1	10	–	48	–
COR22.3	20	100	–	50	–
COR22.4	100	150	6.9	47	1.2
COR22.5	150	200	6.2	58	0.21
COR22.6	200	250	5.8	0.2	0.07
COR22.7	250+		6.6	0.1	nd
COR23.1	0	5	15	0.3	15
COR23.2	5	10	16	59	16
COR23.3	10	25	2.9	–	2.9
COR23.4	25	50	8.3	–	1.3
COR23.5			–	0.1	–
COR23.6			–	6.1	–
COR24.1	0	5	9.5	64	9.5
COR24.2	5	10	9.1	–	8.4
COR24.3	60	75	8.4	0.0	0.70
COR24.4	75	80	–	0.8	–
COR25.1	2	15	2.7	0.1	2.7
COR25.2	40	90	1.9	0.1	1.8
COR25.3	90	115	1.4	–	1.4
COR25.4	115	140	1.3	0.1	1.3
COR26.1	1	120	–	<0.1	–
COR26.2	120	150	1.9	2.8	1.8
COR 27.1	0	20	–	<0.1	–
COR 27.2	20	80	–	0.1	–
COR 27.3	80	90	15	0.2	15
COR28.1	0	15	18	0.1	18
COR28.2	15	50	15	0.1	15
COR28.3	70	100	2.8	<0.1	2.8
COR29.1	0	15	18	<0.1	18
COR29.2	20	50	9.1	0.1	9.1
COR29.3	100	200	9.9	0.1	9.9

C3. Acid Base Accounting

Sample ID	ud	ld	TAA moles $H^+ t^{-1}$	CRS %S	CRS moles $H^+ t^{-1}$	CRS $CaCO_3$ equivalent kg t^{-1}	Carbonate %$CaCO_3$	ANC (Carbonate) kg t^{-1}	NAGP kg t^{-1} w/out factor	NAGP kg t^{-1}
COR1.1	0	5	0	0.15	91	4.6	15	150	-140	-140
COR1.2	5	15	0	0.13	79	4.0	14	140	-130	-130
COR2.1	0	10	–	–	–	–	–	–	–	–
COR2.2	10	40	–	–	–	–	–	–	–	–
COR2.3	40	70	–	0.016	10	0.50	12	120	-120	-120
COR2.4	60	70	0	0.005	3.1	0.16	13	130	-130	-130
COR3.1	0	2	0	0.24	150	7.6	8.7	87	-79	-76
COR4.1	0	5	0	–	–	–	8.0	80		
COR4.2	5	10	–	–	–	–	–	–	–	–
COR4.3	10	40	–	–	–	–	–	–	–	–
COR5.1	0	1	–	–	–	–	–	–	–	–
COR5.2	1	3	–	–	–	–	–	–	–	–
COR5.3			–	–	–	–	–	–	–	–
COR6.1	0	1	0	0.021	13	0.66	39	390	-390	-390
COR6.2	1	3	–	–	–	–	–	–	–	–
COR7.1	0	3	–	–			–			
COR7.2	3	10	0	0.43	270	13	8.9	89	-75	-69
COR8.1	0	5	–	–	–	–	–	–	–	–
COR8.2	5	10	–	–	–	–	–	–	–	–
COR8.3	10	30	–	–	–	–	0.07	0.7	–	–
COR8.4	30	60	0	0.54	340	17	0.60	6.0	11	19
COR8.5	60	110	0	0.43	270	13	4.7	47	-34	-27
COR8.6	110	160	0	0.70	440	22	5.0	50	-28	-17
COR8.7	250	300	0	0.71	440	22	5.8	58	-36	-25
COR9.1	0	5	0	0.10	65	3.3	0.18	1.8	1.45	3.1
COR9.2	15	50	–	0.010	6.3	0.31	0.01	0.1	0.21	0.37
COR10.1	0	3	0	0.098	61	3.1	0.09	0.9	2.2	3.7
COR10.2	3	10	0	0.042	26	1.3	0.11	1.1	0.21	0.87
COR10.3	10	30	0	<0.005	<3	<0.2	0.04	0.4		
COR10.4	30	65	0	0.006	3.8	0.19	0.12	1.2	-1.0	-0.92
COR11.1	0	5	–	–	–	–	–	–	–	–
COR11.2	5	50	–	–	–	–	–	–	–	–
COR11.3	50	60	–	–	–	–	–	–	–	–
COR11.4	60	75	–	–	–	–	–	–	–	–
COR12.1	0	5	0	0.37	230	12	7.0	70	-58	-53
COR13.1	0	5	0	0.043	27	1.3	0.38	3.8	-2.5	-1.8
COR13.2	5	10	–	0.017	11	0.5	0.05	0.5	0.02	0.29
COR13.3	20	45	0	–	–	–	15	150	-150	-150
COR13.4	45	70	0	1.1	680	34	0.37	3.7	30	47
COR14.1	0	5	0	–	–	–	8.6	86	–	–
COR14.2	5	10	0	0.70	440	22	3.1	31	-10	1.2
COR15.1	-1	0	–	–		–	–	–	–	–
COR15.2	0	1	0	1.0	630	31	8.6	86	-54	-38
COR15.3	1	5	0	0.23	140	7.1	0.1	1.1	6	10
COR15.4	23	30	0	–	–	–	–		–	–
COR15.5	30	40	–	–	–	–	27	270	–	–
COR15.6	40	50	0	1.5	940	47	0.9	8.7	38	62
COR15.7	50	60	0	–	–	–	3.5	35	–	–
COR15.8	60	75	–	–	–	–	–	–	–	–
COR15.9	75	100	–	–	–	–	–	–	–	–
COR15.10	100	135	0	0.18	120	5.8	6.0	60	-54	-51
COR16.1	-10	0	0	–			0.1	0.7	–	–
COR16.2	0	10	0	0.02	14	0.72	3.1	31	-30	-30
COR16.3	10	30	0	0.01	5.6	0.28	2.1	21	-20	-20
COR16.4	30	60	0	–	–	–	0.5	4.8	–	–
COR16.5	60	80	0	–	–	–	0.5	4.9	–	–
COR16.6	80	100	0	0.03	20	1.0	0.7	7.4	-6.4	-5.9
COR17.1	0	1	0	0.91	570	28	24	240	-210	-200
COR17.2	1	5	0	0.11	69	3.4	23	230	-230	-220
COR17.3	20	30	0	<0.005	–	–	0.3	3.4	-3.4	-3.4
COR18.1	0	1	0	–		–	0.2	1.8	–	–
COR18.2	1	15	0	0.56	350	17	0.1	0.7	17	25
COR18.3	15	30	–	–	–	–	–	–	–	–
COR18.4	80	90	0	0.005	3.1	0.16	0.2	1.7	-1.5	-1.4
COR18.5	90	120	0	0.10	64	3.2	0.1	1.3	1.9	3.5
COR18.6	120	140	0	2.2	1300	67	0.1	0.8	67	100

Sample ID	ud	ld	TAA moles $H^+ t^{-1}$	CRS %S	CRS moles $H^+ t^{-1}$	CRS $CaCO_3$ equivalent kg t^{-1}	Carbonate $\%CaCO_3$	Carbonate kg t^{-1}	NAGP kg t^{-1} w/out factor	NAGP kg t^{-1}
COR19.1	0	5	0	0.57	360	18	2.0	20	-2.2	6.7
COR19.2	5	15	0	0.60	370	19	1.4	14	5.1	14
COR19.3	15	20	0	0.30	190	9.3	31	310	-300	-290
COR20.1	0	30	0	0.21	130	6.7	23	230	-230	-220
COR21.1	0	1	0	–	–	–	22	220	–	–
COR21.2	1	5	0	–	–	–	38	380	–	–
COR21.3	10	50	0	0.024	15	0.75	54	540	-540	-540
COR21.4	50	100	0	0.53	330	17	55	550	-530	-520
COR22.1	-1	0	0	–	–	–	47	470	–	–
COR22.2	1	10	0	–	–	–	26	260	–	–
COR22.3	20	100	0	–	–	–	61	610	–	–
COR22.4	100	150	0	0.50	320	16	48	480	-460	-450
COR22.5	150	200	0	0.57	360	18	50	500	-480	-470
COR22.6	200	250	0	0.42	260	13	47	470	-460	-460
COR22.7			0	0.48	300	15	58	580	-560	-560
COR23.1	0	5	0	0.034	21	1.1	0.2	1.8	-0.78	-0.24
COR23.2	5	10	0	0.036	23	1.1	0.1	1.1	0.01	0.57
COR23.3	10	25	0	0.082	51	2.6	0.3	3.4	-0.79	0.49
COR23.4	25	50	0	0.22	140	6.9	59	590	-580	-580
COR23.5			–	–	–	–	–	–	–	–
COR23.6			–	–	–	–	–	–	–	–
COR24.1	0	5	0	0.81	500	25	0.1	0.5	25	37
COR24.2	5	10	0	0.81	510	25	6.1	61	-36	-23
COR24.3	60	75	0	0.49	310	15	64	640	-620	-610
COR24.4	75	80	–	–			–			
COR25.1	2	15	0	0.086	54	2.7	0.0	0.2	2.5	3.9
COR25.2	40	90	0	0.062	39	1.9	0.8	8.3	-6.4	-5.4
COR25.3	90	115	0	0.031	19	1.0	0.1	0.7	0.23	0.71
COR25.4	115	140	0	0.043	27	1.3	0.1	1.0	0.37	1.0
COR26.1	1	120	–	–	–	–	–	–	–	–
COR26.2	120	150	X	0.067	42	2.1	0.1	1.0	1.1	2.1
COR 27.1	0	20	X	–	–	–	0.0	0.2	–	–
COR 27.2	20	80	X	–	–	–	2.8	28	–	–
COR 27.3	80	90	X	0.31	190	9.6	<0.1		10	14
COR28.1	0	15	X	0.16	100	5.0	0.1	0.6	4	7
COR28.2	15	50	0	0.66	410	20	0.2	1.8	19	29
COR28.3	70	100	0	1.8	1100	57	0.1	1.2	56	84
COR29.1	0	15	0	0.22	140	6.8	0.1	1.0	6	9
COR29.2	20	50	0	0.38	240	12	0.0	0.3	12	17
COR29.3	100	200	0	7.6	4700	237	0.0	0.2	240	360

C4. XRF

4.1 Major elements

Sample	Si	Al	Mg	Fe	Ca	Na	K	Ti	P	Mn	S	Cl
							%					
COR1.1	104	21	4.6	8.6	12	1.4	1.7	1.6	0.55	0.046	0.50	0.20
COR1.2	105	23	4.4	9.5	11	1.3	1.8	1.7	0.55	0.045	0.50	0.22
COR2.3	163	8.4	4.4	1.6	6.0	3.1	1.6	0.4	0.14	0.023	0.70	1.6
COR2.4	152	10	5.9	3.0	6.1	3.9	1.6	0.8	0.16	0.034	0.95	2.2
COR3.1	97	28	9.2	11	5.7	3.7	2.4	1.8	0.34	0.066	3.0	2.3
COR4.1	100	24	8.8	9.5	5.6	5.9	2.2	1.5	0.30	0.056	4.6	4.2
COR6.1	51	17	6.5	5.9	28	1.2	1.8	0.81	0.70	0.058	2.4	0.47
COR7.1	44	9.2	8.0	4.2	20	9.5	1.1	0.48	1.1	0.034	6.3	3.9
COR7.2	97	31	9.2	11	5.1	2.1	3.0	1.6	0.41	0.054	1.1	0.58
COR8.3	124	29	2.5	11	0.55	5.3	1.7	2.2	0.14	0.017	1.4	2.7
COR8.4	172	9.1	1.2	3.0	0.92	3.6	0.84	0.80	0.07	0.009	4.4	2.1
COR8.5	176	6.8	0.9	2.0	4.0	2.8	0.75	0.70	0.07	0.009	3.7	1.6
COR8.6	173	6.9	1.0	2.5	4.2	2.7	0.71	0.68	0.07	0.009	4.5	1.5
COR8.7	174	6.1	0.9	2.4	5.5	2.2	0.63	0.52	0.07	0.008	4.8	1.2
COR9.1	145	20	1.3	7.0	0.80	1.4	0.60	1.1	0.25	0.025	0.52	0.75
COR9.2	181	8.9	0.8	5.1	0.59	0.59	0.28	0.62	0.09	0.010	0.42	0.23
COR10.1	96	27	2.0	13	1.4	0.92	2.0	1.3	0.82	0.091	2.5	0.22
COR10.2	120	31	2.1	10	1.0	0.86	2.4	1.6	0.44	0.039	0.57	0.15
COR10.3	204	4.6	0.3	1.3	0.17	0.47	0.53	0.43	0.05	0.009	0.20	0.081
COR10.4	163	20	1.3	4.0	0.73	1.3	1.5	0.93	0.18	0.015	0.85	0.45
COR12.1	105	16	2.0	5.5	6.1	1.7	1.3	1.0	0.80	0.12	0.82	0.58
COR13.1	165	16	1.0	3.9	1.1	1.0	1.3	1.2	0.16	0.021	0.67	0.14
COR13.2	179	12	0.7	2.2	0.94	1.1	1.0	0.92	0.09	0.009	0.55	0.10
COR13.3	127	8.1	0.7	8.7	19	1.1	0.6	0.87	0.14	0.017	16	0.37
COR13.4	145	26	1.5	10	0.92	1.1	1.7	2.2	0.14	0.018	6.1	0.24
COR14.1	89	12	4.9	7.9	9.8	9.4	1.0	1.4	0.44	0.13	3.6	7.4
COR14.2	143	18	1.9	8.5	2.8	2.5	1.3	2.2	0.16	0.026	4.3	1.2
COR15.2	20	5.0	6.5	4.2	9.9	23	1.4	0.20	0.78	0.032	4.0	21
COR15.3	79	10	4.1	2.6	1.7	16	1.4	0.52	0.32	0.009	7.2	12
COR15.5	144	3.9	1.1	1.5	14	3.8	0.6	0.35	0.09	0.005	3.2	2.7
COR15.6	53	3.8	4.7	3.8	3.1	17	1.0	0.28	0.21	0.023	3.0	14
COR15.7	116	3.1	2.7	1.4	4.1	12	0.75	0.32	0.16	0.012	1.4	8.8
COR15.10	187	4.6	0.7	1.3	3.4	1.2	0.69	0.43	0.02	0.006	1.5	0.73
COR16.2	139	28	2.4	9.4	3.3	0.28	2.4	1.5	0.07	0.035	0.3	0.026
COR16.3	161	20	1.8	6.5	2.1	0.38	1.9	1.3	0.09	0.023	0.2	0.010
COR16.4	170	17	1.9	6.2	0.62	0.49	1.9	1.3	0.09	0.014	0.10	0.007
COR16.5	175	15	1.7	5.1	0.62	0.49	1.7	1.3	0.09	0.012	0.12	0.009
COR16.6	166	18	2.5	6.3	1.3	0.43	2.0	1.3	0.09	0.015	0.15	0.014
COR17.1	6.8	23	3.0	7.2	34	9.0	0.39	0.09	0.40	0.023	10	6.8
COR17.2	15	55	3.9	6.4	19	7.7	0.44	0.17	0.67	0.030	5.2	5.7
COR17.3	81	12	3.8	4.4	2.0	9.5	1.7	0.93	0.23	0.013	1.6	6.3
COR17.4	101	1.6	0.5	0.3	35	2.0	0.33	0.21	0.02	0.003	0.69	1.0
COR18.1	177	8.1	0.9	2.8	0.59	2.0	0.94	0.62	0.09	0.009	0.70	1.3
COR18.2	184	4.8	0.8	1.6	0.27	2.8	0.63	0.42	0.09	0.005	0.80	1.9
COR18.4	123	35	3.2	12	0.31	2.4	3.3	2.0	0.18	0.025	0.70	1.0
COR18.5	146	25	2.0	7.7	0.32	1.9	2.4	1.6	0.09	0.013	1.7	0.79
COR18.6	116	38	2.4	14	0.28	1.8	3.2	1.5	0.11	0.034	11	0.64
COR19.1	100	6.0	2.5	2.5	3.1	4.7	0.8	0.52	0.32	0.006	1.1	2.7
COR19.2	55	8.2	3.8	3.7	4.7	9.3	1.1	0.52	0.48	0.009	2.1	6.6
COR19.3	133	4.5	1.0	2.1	19	2.0	0.64	0.38	0.14	0.009	2.2	1.2
COR20.1	160	2.9	0.8	1.4	14	1.3	0.45	0.55	0.09	0.010	1.7	0.69
COR21.1	11	1.2	5.6	0.6	34	17	0.58	0.10	0.11	0.015	68	8.0
COR21.2	91	7.9	2.2	2.3	29	4.0	1.0	0.45	0.18	0.015	2.5	2.4
COR21.3	98	4.0	2.2	1.1	36	1.5	0.65	0.23	0.14	0.013	1.2	0.46
COR21.4	83	5.1	2.6	1.9	39	1.7	0.71	0.30	0.14	0.015	5.0	0.65
COR22.1	74	3.9	3.7	1.1	37	5.1	0.69	0.20	0.14	0.014	12	2.6
COR22.2	126	6.6	1.4	1.4	21	2.0	1.0	0.38	0.25	0.017	0.9	0.71

Sample	Si	Al	Mg	Fe	Ca	Na	K	Ti	P	Mn	S	Cl
							%					
COR22.3	67	4.3	2.7	1.6	47	1.1	0.60	0.22	0.14	0.018	1.1	0.16
COR22.4	84	5.0	2.4	1.8	40	1.0	0.65	0.28	0.14	0.014	4.2	0.14
COR22.5	95	4.7	2.2	1.8	37	0.9	0.63	0.23	0.14	0.014	4.2	0.12
COR22.6	101	4.3	2.1	1.4	35	1.0	0.60	0.22	0.14	0.013	3.1	0.12
COR22.7	86	4.9	2.4	1.7	40	1.0	0.66	0.27	0.16	0.015	3.8	0.12
COR23.1	57	13	4.0	2.9	1.8	15	1.8	0.77	1.1	0.012	2.8	11
COR23.2	61	13	3.9	4.0	1.7	13	1.8	0.80	1.3	0.017	1.9	9.9
COR23.3	130	26	2.6	5.3	1.1	4.3	2.9	1.6	0.44	0.013	1.2	2.5
COR23.4	60	6.0	1.3	1.6	43	4.3	0.75	0.43	0.21	0.005	2.9	2.8
COR24.1	80	17	3.9	5.0	3.5	12	2.3	1.0	0.82	0.015	2.4	9.1
COR24.2	83	17	3.5	5.1	6.5	10	2.2	1.0	0.71	0.015	2.6	7.4
COR25.1	151	24	1.7	5.5	0.57	3.2	2.4	1.0	0.30	0.050	0.65	0.036
COR25.2	151	25	1.8	6.0	1.2	3.0	2.3	1.1	0.32	0.054	0.45	0.022
COR25.3	151	26	1.8	6.1	0.64	3.1	2.4	1.1	0.30	0.074	0.35	0.021
COR25.4	137	32	2.0	8.0	0.69	2.7	2.5	1.5	0.41	0.094	0.37	0.028
COR26.2	162	21	1.2	3.8	0.35	2.2	2.2	1.0	0.21	0.034	0.47	0.011
COR27.1	109	24	1.3	5.6	0.36	1.9	1.8	1.2	0.48	0.015	0.60	0.16
COR28.1	82	18	1.1	14	1.1	1.3	0.8	0.88	0.66	0.009	1.1	0.50
COR28.2	86	25	1.4	12	1.0	1.3	1.1	1.1	0.47	0.009	4.8	0.48
COR28.3	154	21	0.9	5.8	0.56	2.1	1.8	1.3	0.09	0.019	6.9	0.15
COR29.1	76	19	2.0	9.3	1.0	3.3	1.2	0.92	0.89	0.013	2.9	1.5
COR29.2	110	29	2.2	5.8	0.73	2.6	1.7	1.3	0.64	0.014	1.6	0.91
COR29.3	88	22	2.1	16	0.67	3.4	1.4	1.0	0.24	0.060	53	1.4

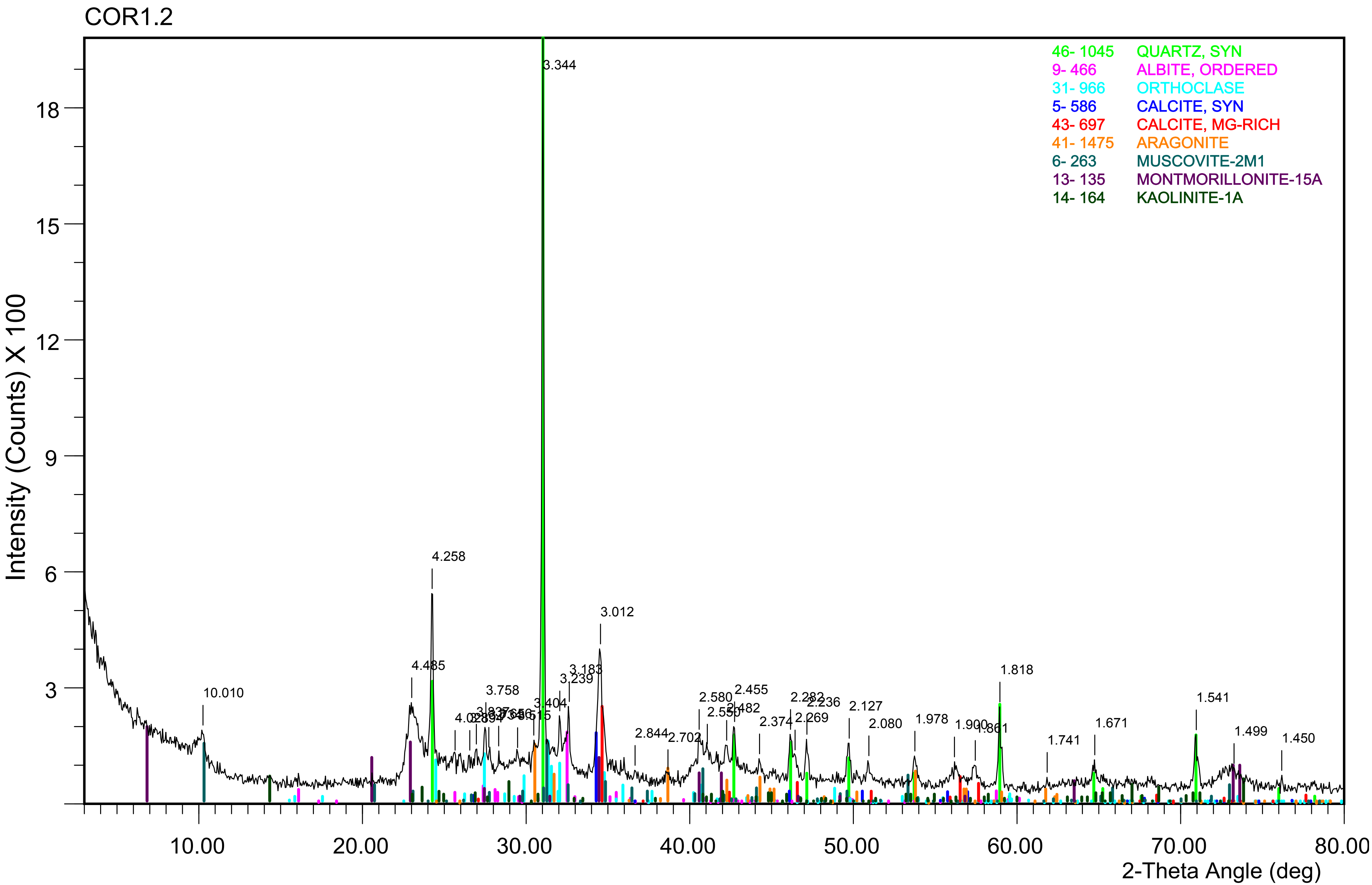
4.2 Minor elements

		Zn	Cu	Sr	Zr	Ni	Rb	Ba	V	Cr	La	Ce	Pb	Y	Co	Ga	U	Th	As	Sn
ANZECC	ISQG-upper	410	270			52				370			220						70	
	ISQG-lower	200	65			21				80			50						20	
Sample										mg kg^{-1}										
COR1.1		95	<15	517	512	95	101	257	262	195	104	143	<19	69	50	30	16	23	31	<23
COR1.2		113	<15	460	506	125	109	217	265	233	100	158	<19	68	39	36	18	21	30	<23
COR2.3		6	<15	496	319	30	55	404	63	<25	34	57	<19	19	86	<9	<15	<15	30	<23
COR2.4		19	<15	549	1125	26	59	500	121	<25	44	56	<19	36	31	15	<15	<15	39	<23
COR3.1		80	<15	558	326	76	96	208	438	184	61	118	<19	46	32	34	<15	<15	60	<23
COR4.1		60	<15	542	305	60	88	224	357	137	68	95	<19	38	31	25	<15	<15	51	<23
COR6.1		64	<15	5703	272	72	101	674	319	92	123	136	<19	45	25	27	36	61	62	<23
COR7.1		46	<15	1429	199	95	71	199	188	40	90	85	<19	29	18	26	51	161	116	<23
COR7.2		91	<15	482	294	107	148	344	427	240	61	118	25	47	35	39	<15	20	49	<23
COR8.3		55	<15	141	426	66	93	299	436	192	72	116	<19	51	28	34	<15	<15	58	<23
COR8.4		24	<15	105	686	26	32	227	172	28	44	54	<19	26	111	<9	<15	<15	28	<23
COR8.5		13	<15	196	741	21	29	236	106	<25	35	49	<19	26	129	<9	<15	<15	30	<23
COR8.6		14	<15	194	693	<20	26	165	120	<25	41	66	<19	19	128	<9	<15	<15	28	<23
COR8.7		9	<15	205	403	<20	23	216	118	<25	43	47	<19	16	184	<9	<15	<15	30	<23
COR9.1		123	<15	180	391	34	53	305	363	84	47	62	<19	31	97	24	<15	<15	31	<23
COR9.2		32	<15	86	247	32	18	359	293	66	33	55	<19	<15	153	9.4	<15	<15	46	<23
COR10.1		177	18	172	266	63	140	410	404	126	88	162	49	45	49	38	36	66	297	<23
COR10.2		137	<15	155	364	62	153	493	394	144	59	131	49	54	31	40	15	16	129	<23
COR10.3		13	<15	34	590	<20	22	159	86	<25	29	44	<19	16	33	2.6	<15	<15	28	<23
COR10.4		48	<15	102	291	55	100	253	247	72	40	85	<19	39	31	21	<15	<15	46	<23
COR12.1		84	<15	356	579	55	78	293	227	67	46	84	<19	35	31	23	<15	<15	77	<23
COR13.1		47	<15	126	1366	42	70	247	217	66	58	64	<19	39	21	19	<15	<15	60	<23
COR13.2		28	<15	125	1212	30	49	230	194	44	40	55	<19	35	<15	12	<15	<15	27	<23
COR13.3		39	<15	573	850	64	34	244	354	82	86	84	<19	33	30	19	<15	<15	170	<23
COR13.4		44	<15	88	840	81	88	177	404	180	82	168	<19	70	55	32	<15	<15	52	<23
COR14.1		93	<15	735	440	46	57	301	234	63	48	78	<19	38	38	17	<15	<15	41	<23
COR14.2		63	<15	229	717	75	70	319	325	152	70	101	<19	46	32	22	<15	<15	30	<23
COR15.2		698	21	692	114	50	51	58	128	<25	28	7	77	21	35	8	16	<15	68	<23
COR15.3		125	35	205	195	86	69	107	218	<25	64	62	150	21	19	9	22.3	34.8	20	<23
COR15.5		6	<15	534	260	<20	29	89	76	<25	45	48	<19	20	28	<9	<15	<15	28	<23
COR15.6		35	<15	285	260	31	54	58	220	<25 <25	31	18	<19	35	34	13	144	<15	49	<23
COR15.7		13	<15	264	341	<20	42	161	114		17	10	91	18	25	<9	33	<15	25	<23
COR15.10		8	<15	131	381	26	24	132	76	<25	33	44	<19	<15	24	<9	<15	<15	26	<23

		Zn	Cu	Sr	Zr	Ni	Rb	Ba	V	Cr	La	Ce	Pb	Y	Co	Ga	U	Th	As	Sn
ANZECC	ISQG-upper	410	270			52				370			220						70	
	ISQG-lower	200	65			21				80			50						20	
Sample										mg	kg^{-1}									
COR16.2		92	<15	119	535	82	115	380	408	141	54	125	<19	51	41	40	<15	23	38	<23
COR16.3		45	<15	96	588	58	79	330	275	127	48	88	<19	33	26	19	<15	<15	33	<23
COR16.4		35	<15	79	789	136	73	269	303	191	50	97	<19	49	<15	20	<15	<15	36	<23
COR16.5		32	<15	74	824	45	64	188	225	68	57	93	<19	41	<15	16	<15	<15	28	<23
COR16.6		34	<15	112	741	54	77	230	264	83	39	80	<19	41	20	20	<15	<15	39	<23
COR17.1		76	21	335	131	179	36	<39	169	69	117	56	<19	28	36	28	48	41	74	<23
COR17.2		178	75	379	130	229	29	<39	384	<25	81	79	37	28	47	35	42	22	76	<23
COR17.3		46	<15	220	775	62	93	134	660	27	41	67	<19	54	40	19	73	17	23	<23
COR17.4		9	<15	1130	339	56	28	79	50	<25	112	76	<19	33	<15	<9	37	30	39	<23
COR18.1		19	<15	65	172	23	39	314	143	<25	38	56	<19	16	30	9	<15	<15	23	<23
COR18.2		36	<15	31	158	<20	25	131	94	<25	34	32	<19	<15	41	<9	<15	<15	15	<23
COR18.4		74	<15	99	389	90	153	452	657	213	80	126	19	63	28	48	<15	20	100	<23
COR18.5		49	<15	72	634	60	107	260	375	120	47	96	<19	52	26	29	16	<15	39	<23
COR18.6		56	<15	76	351	109	144	355	448	177	75	138	<19	56	42	47	<15	<15	67	<23
COR19.1		104	<15	252	525	32	58	128	158	<25	27	44	<19	27	33	11	18	<15	20	<23
COR19.2		131	<15	347	282	52	90	278	214	<25	39	42	<19	26	44	17	27	25	23	<23
COR19.3		61	<15	615	344	<20	34	294	106	<25	66	39	<19	21	25	<9	<15	14	42	<23
COR20.1		11	<15	484	795	21	23	230	107	<25	59	53	<19	30	29	<9	<15	17	37	<23
COR21.1		35	<15	2328	135	24	20	<39	23	<25	60	35	<19	20	21	<9	<15	20	54	<23
COR21.2		42	<15	1301	264	36	41	134	188	39	93	65	61	37	26	11	<15	17	75	<23
COR21.3		17	<15	1559	282	<20	34	152	62	<25	102	67	<19	36	23	12	<15	27	77	<23
COR21.4		13	<15	1801	306	23	34	146	117	<25	104	69	<19	32	28	11	<15	18	82	<23
COR22.1		13	<15	1893	209	<20	30	160	64	<25	90	47	<19	31	17	10	<15	20	71	<23
COR22.2		12	<15	887	369	<20	40	206	113	<25	71	66	<19	28	15	10	<15	14	56	<23
COR22.3		18	<15	2256	241	25	38	135	108	<25	125	83	<19	44	14	16	15	26	81	<23
COR22.4		16	<15	1748	245	24	30	147	125	<25	102	77	<19	31	22	13	<15	<15	81	<23
COR22.5		16	<15	1576	240	21	30	167	108	<25	109	67	<19	36	21	12	18	22	73	<23
COR22.6		13	<15	1466	254	<20	30	161	94	<25	81	46	<19	31	20	11	19	23	74	<23
COR22.7		12	<15	1734	288	29	37	126	126	<25	114	92	<19	37	27	11	18	32	78	<23
COR23.1		52	<15	224	305	65	121	181	286	<25	22	38	<19	38	35	23	38	28	29	<23
COR23.2		48	<15	215	267	51	114	172	362	<25	40	55	<19	25	24	20	23	18	84	<23
COR23.3		63	<15	149	462	57	155	403	351	153	64	106	<19	47	23	26	<15	<15	31	<23
COR23.4		26	<15	1459	300	45	47	130	166	<25	136	57	<19	37	18	17	<15	19	77	<23

		Zn	Cu	Sr	Zr	Ni	Rb	Ba	V	Cr	La	Ce	Pb	Y	Co	Ga	U	Th	As	Sn
ANZECC	ISQG-upper	410	270			52				370			220						70	
	ISQG-lower	200	65			21				80			50						20	
Sample										mg	kg–1									
COR24.1		125	21	248	311	62	119	268	303	73	59	68	19	44	29	22	20	15	38	<23
COR24.2		124	32	329	311	57	109	291	334	93	49	55	<19	37	29	21	<15	<15	47	<23
COR25.1		111	<15	287	442	25	87	591	273	<25	36	84	<19	38	30	26	<15	<15	14	<23
COR25.2		124	<15	301	422	30	89	586	297	<25	39	49	19	35	34	28	<15	<15	12	<23
COR25.3		124	<15	299	411	24	93	606	278	<25	36	73	<19	36	33	26	<15	<15	16	<23
COR25.4		134	<15	303	394	42	114	650	365	<25	67	96	<19	48	29	36	<15	<15	17	<23
COR26.2		116	<15	163	456	24	85	567	225	27	39	74	<19	38	52	22	<15	<15	15	<23
COR27.1		73	<15	148	298	22	90	442	308	27	55	72	<19	50	<15	29	17	<15	8	<23
COR28.1		82	<15	147	339	<20	65	225	336	45	52	85	<19	40	<15	31	<15	<15	15	<23
COR28.2		80	<15	143	266	31	88	242	441	67	90	151	27	47	<15	33	37	24	32	<23
COR28.3		76	<15	191	652	33	76	365	294	45	43	98	<19	45	41	22	<15	<15	35	<23
COR29.1		73	<15	184	293	38	84	153	362	50	83	142	<19	46	12	34	51	31	52	<23
COR29.2		82	<15	180	338	41	114	267	543	59	82	148	<19	66	23	39	40	26	47	<23
COR29.3		92	<15	121	160	22	68	180	456	40	95	160	<19	27	57	19	<15	<15	65	<23

C5. XRD patterns



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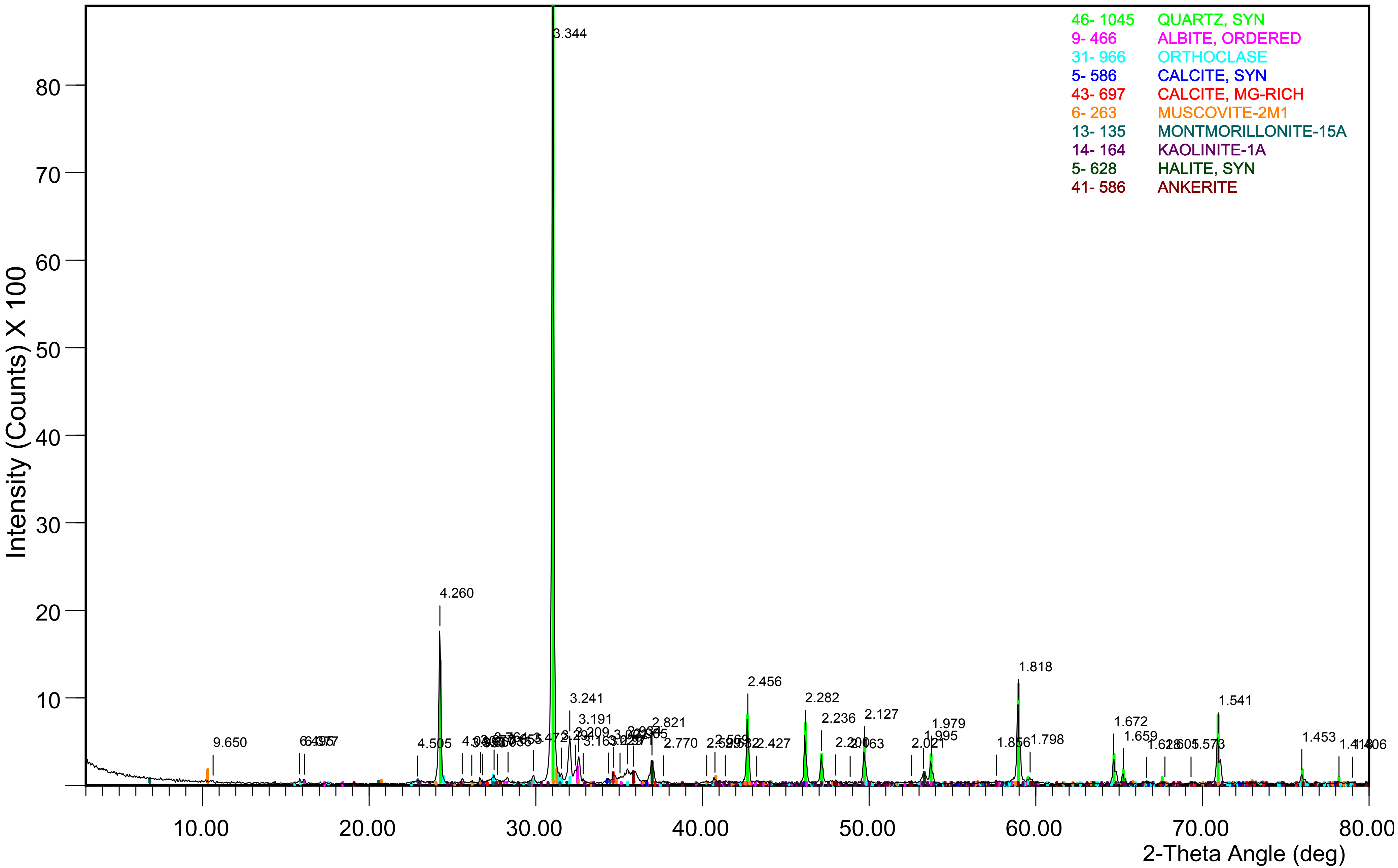
COR2.3



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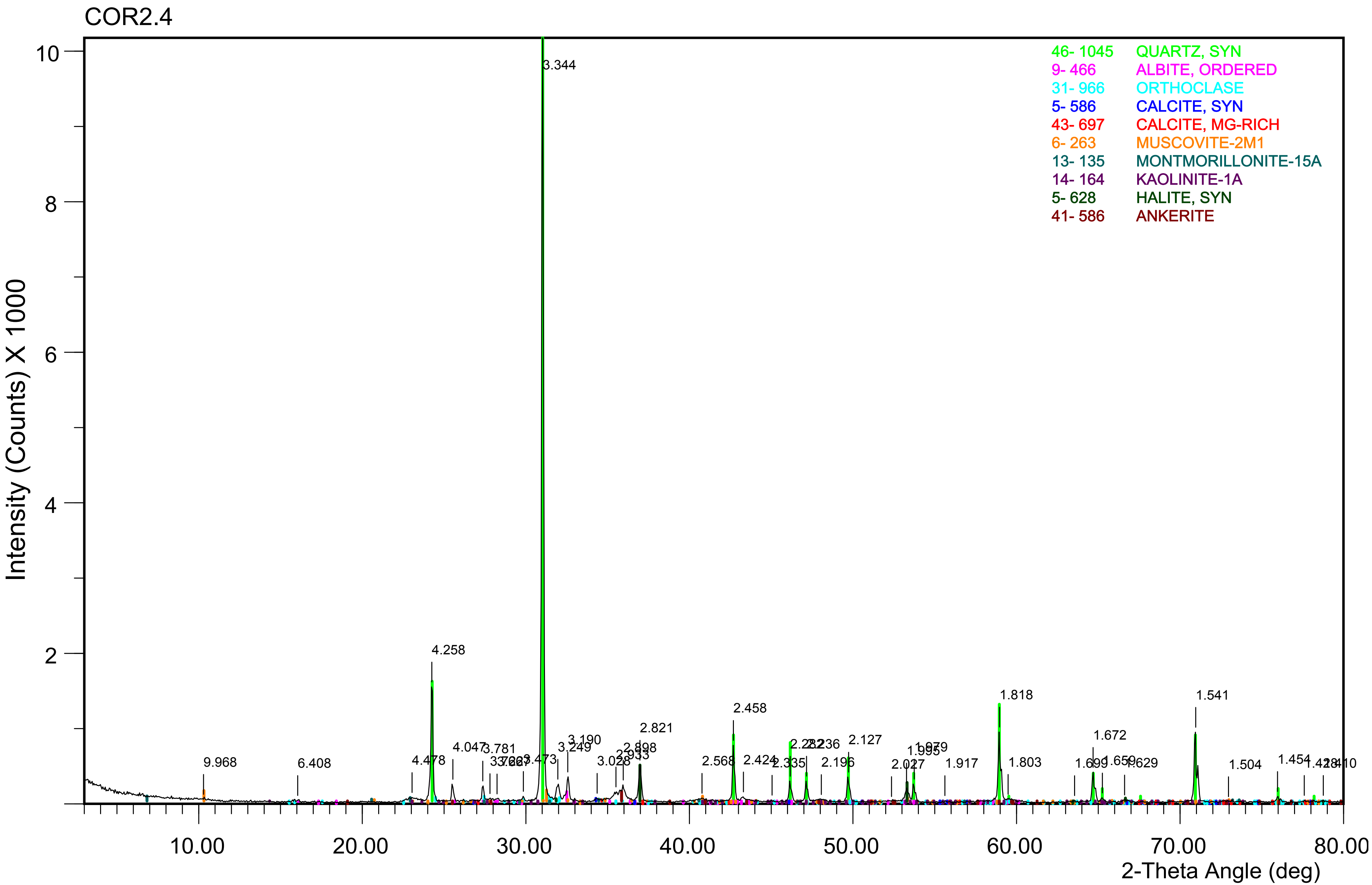
CSIRO Land and Water



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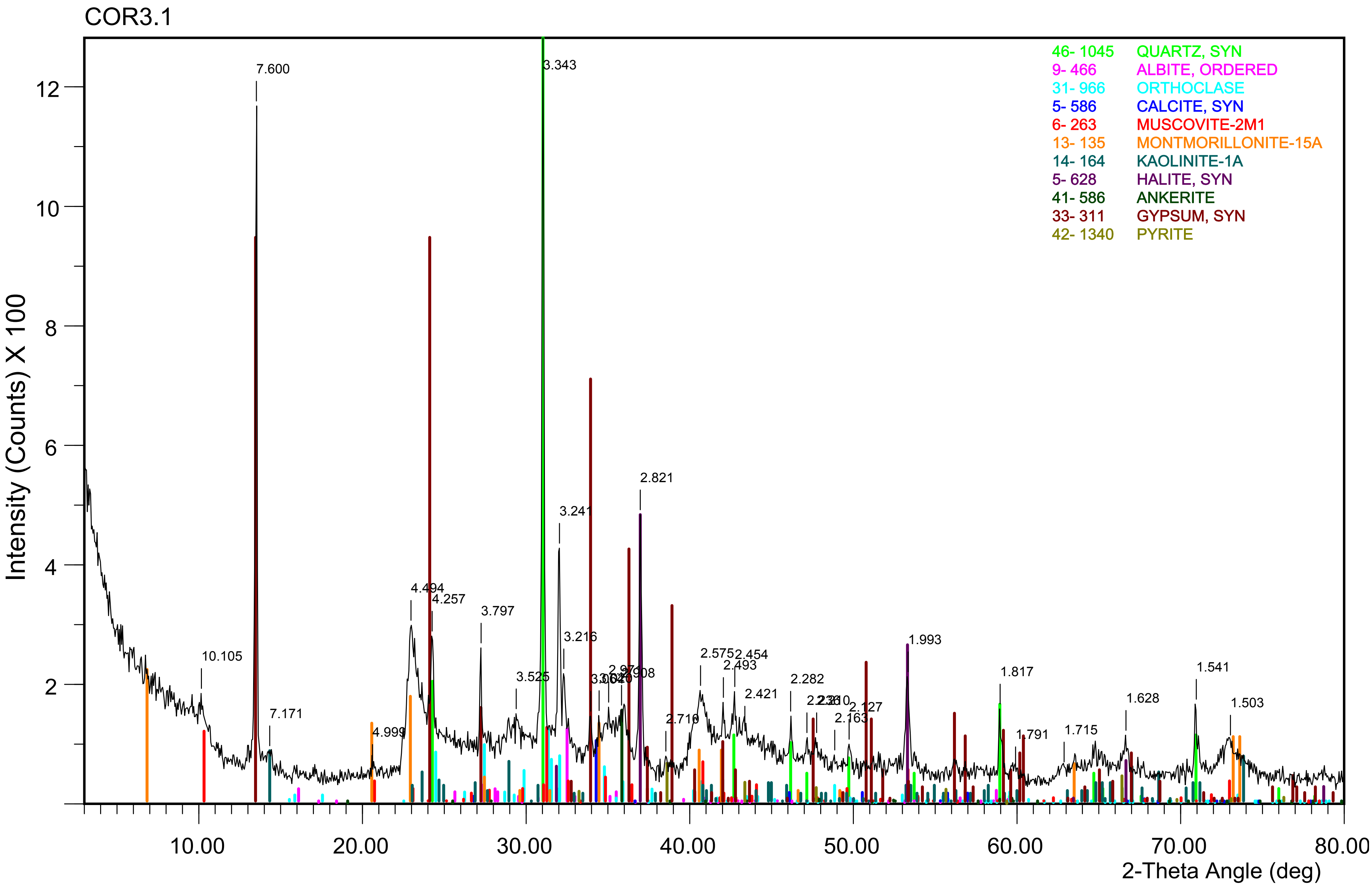

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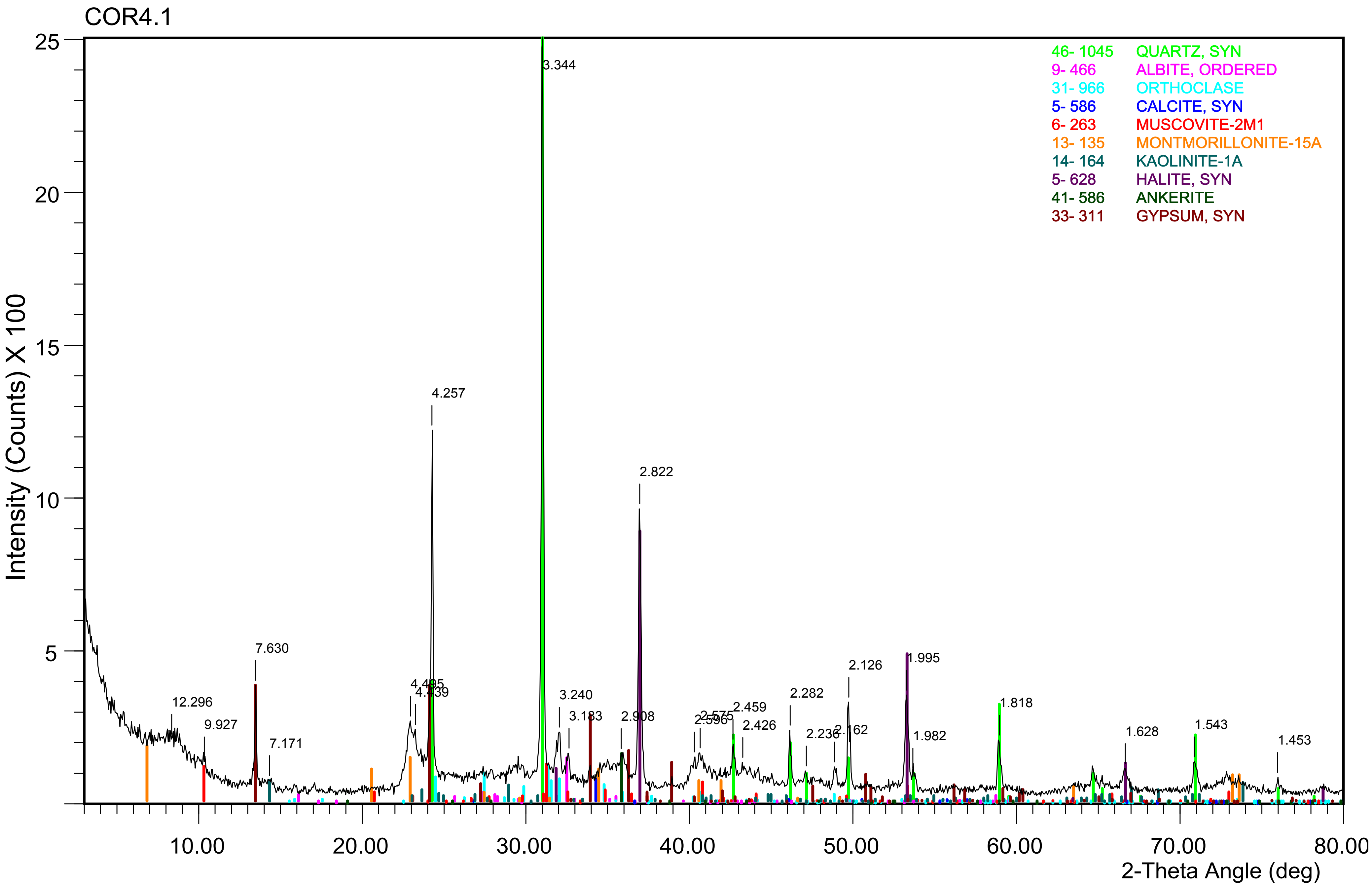

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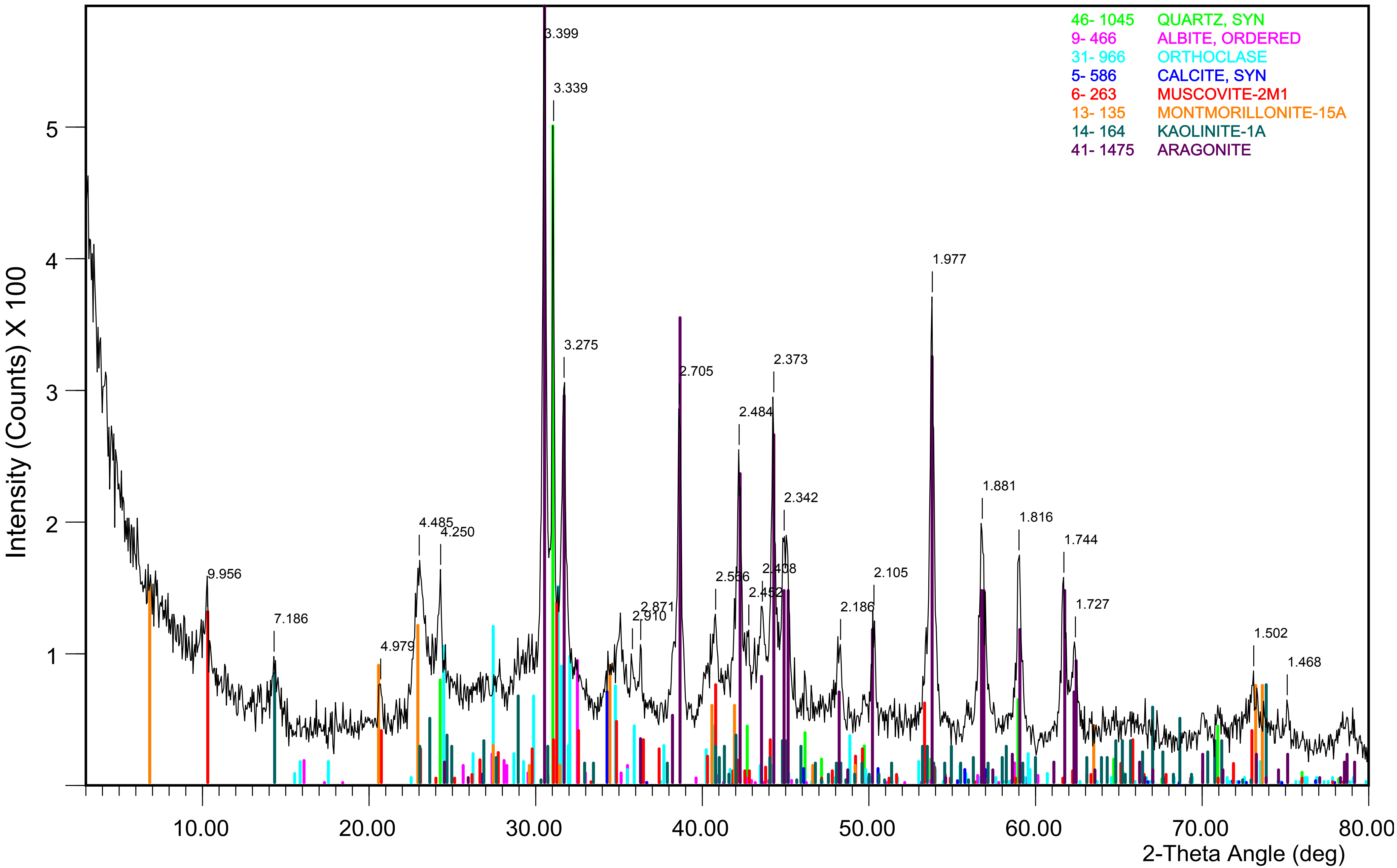
COR6.1



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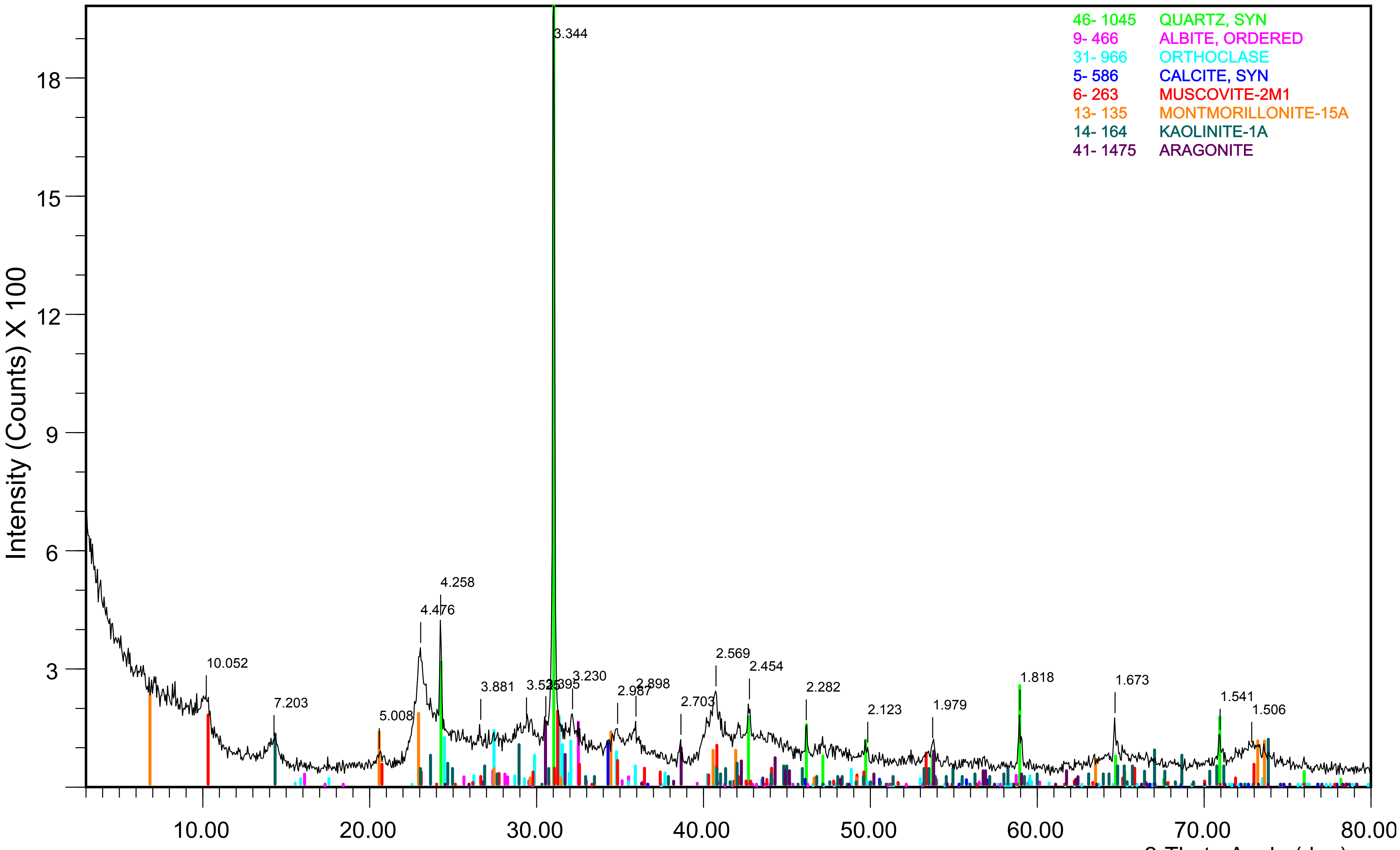
COR7.2



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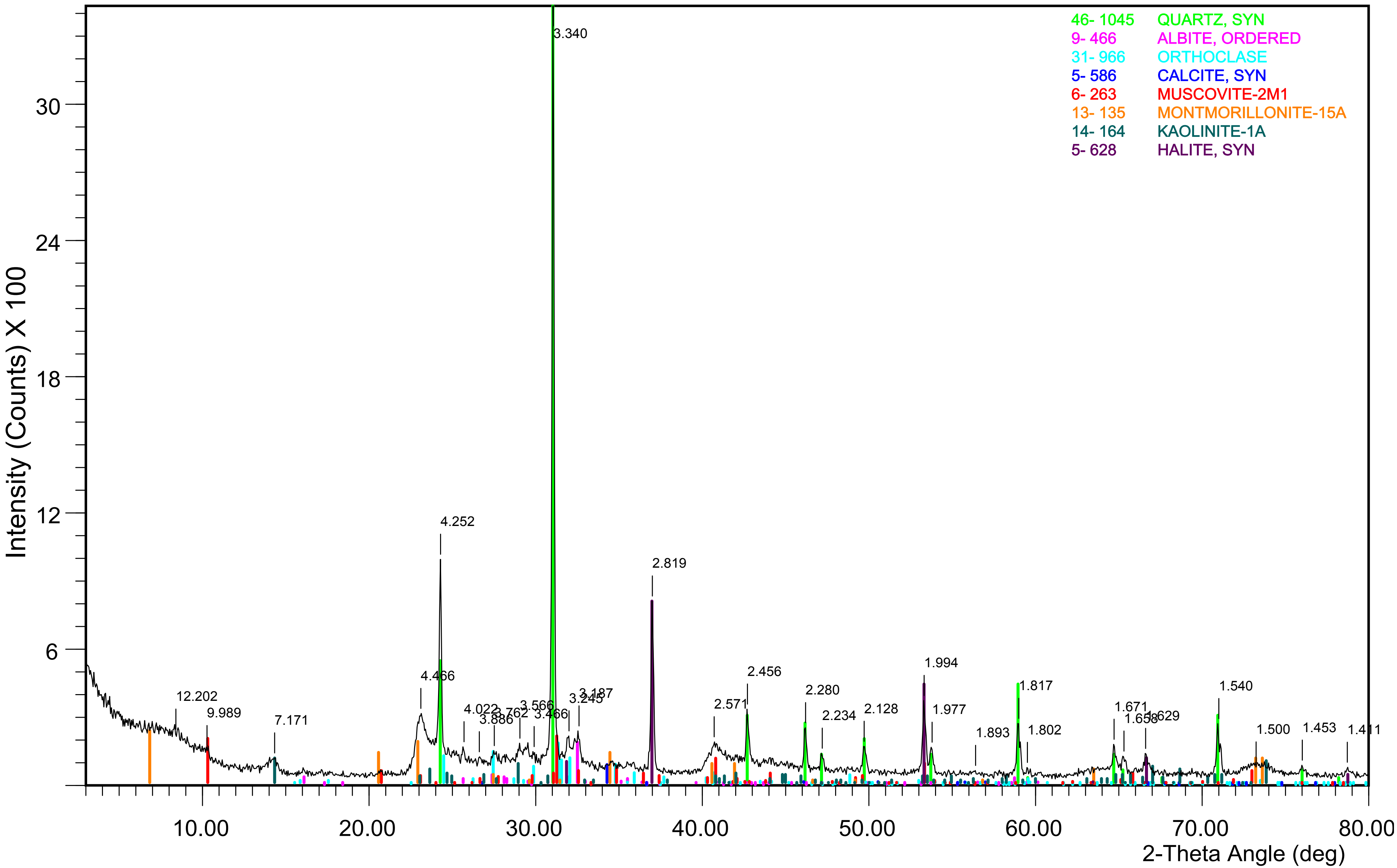
COR8.3



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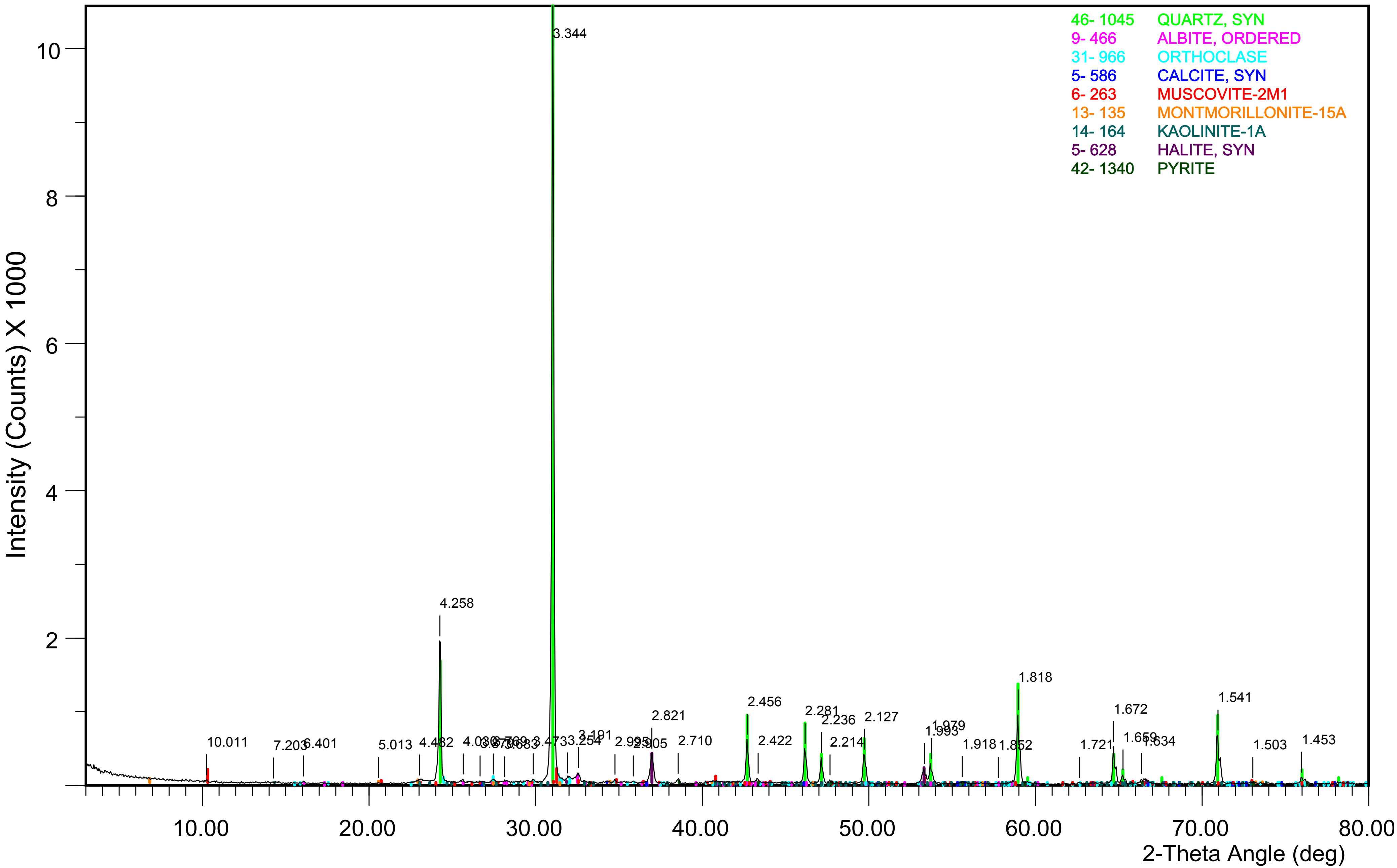
COR8.4



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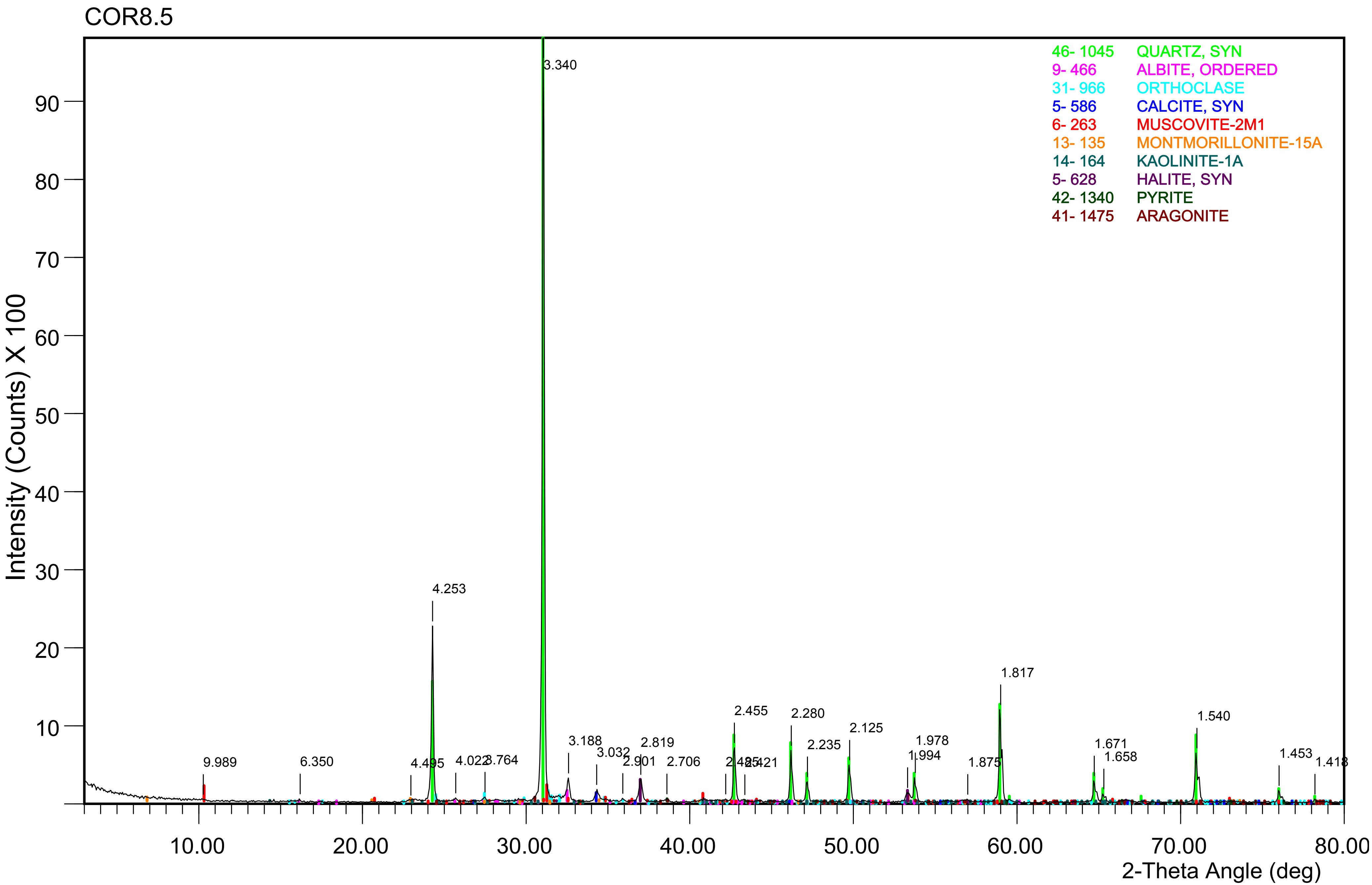

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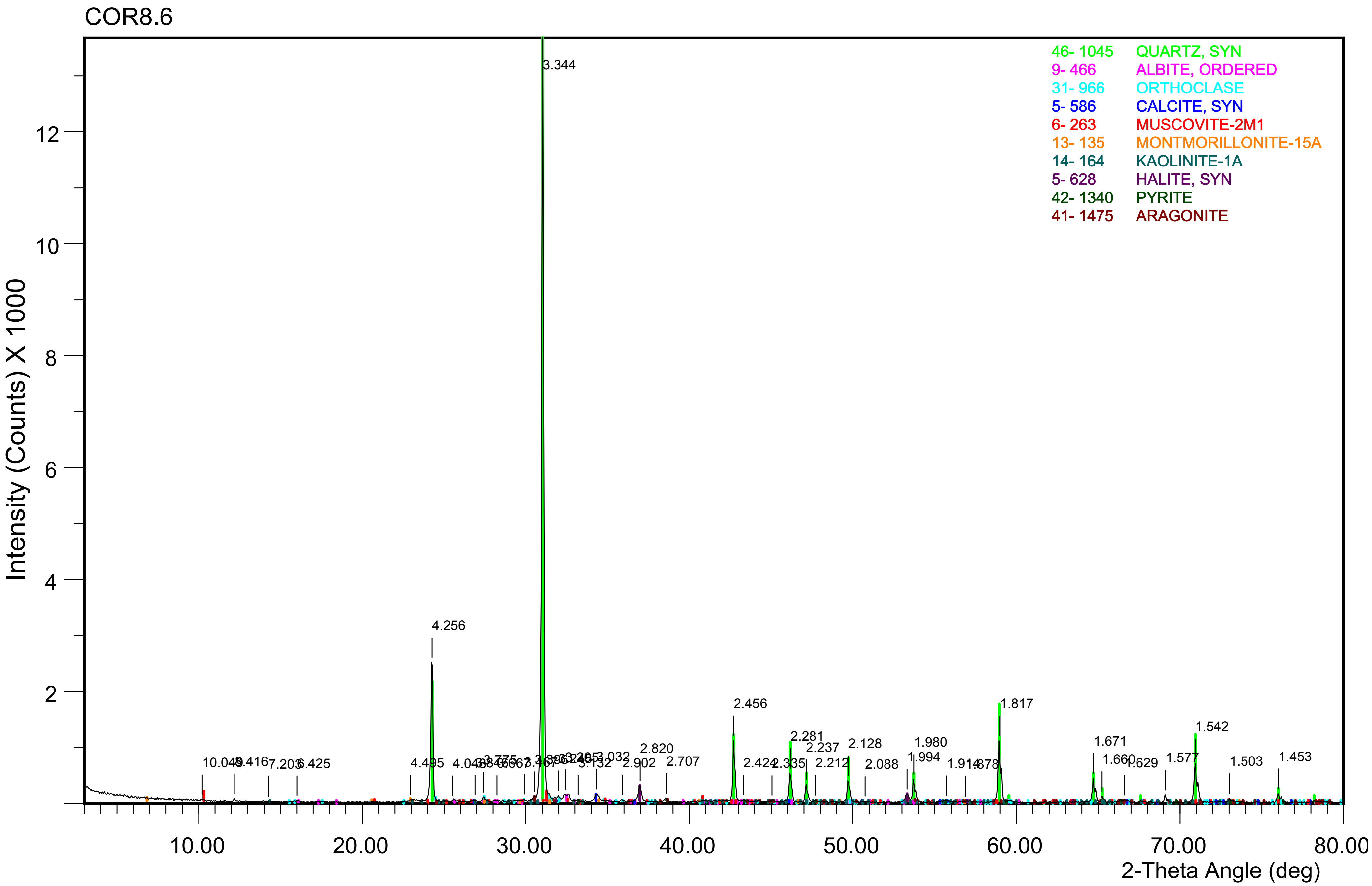

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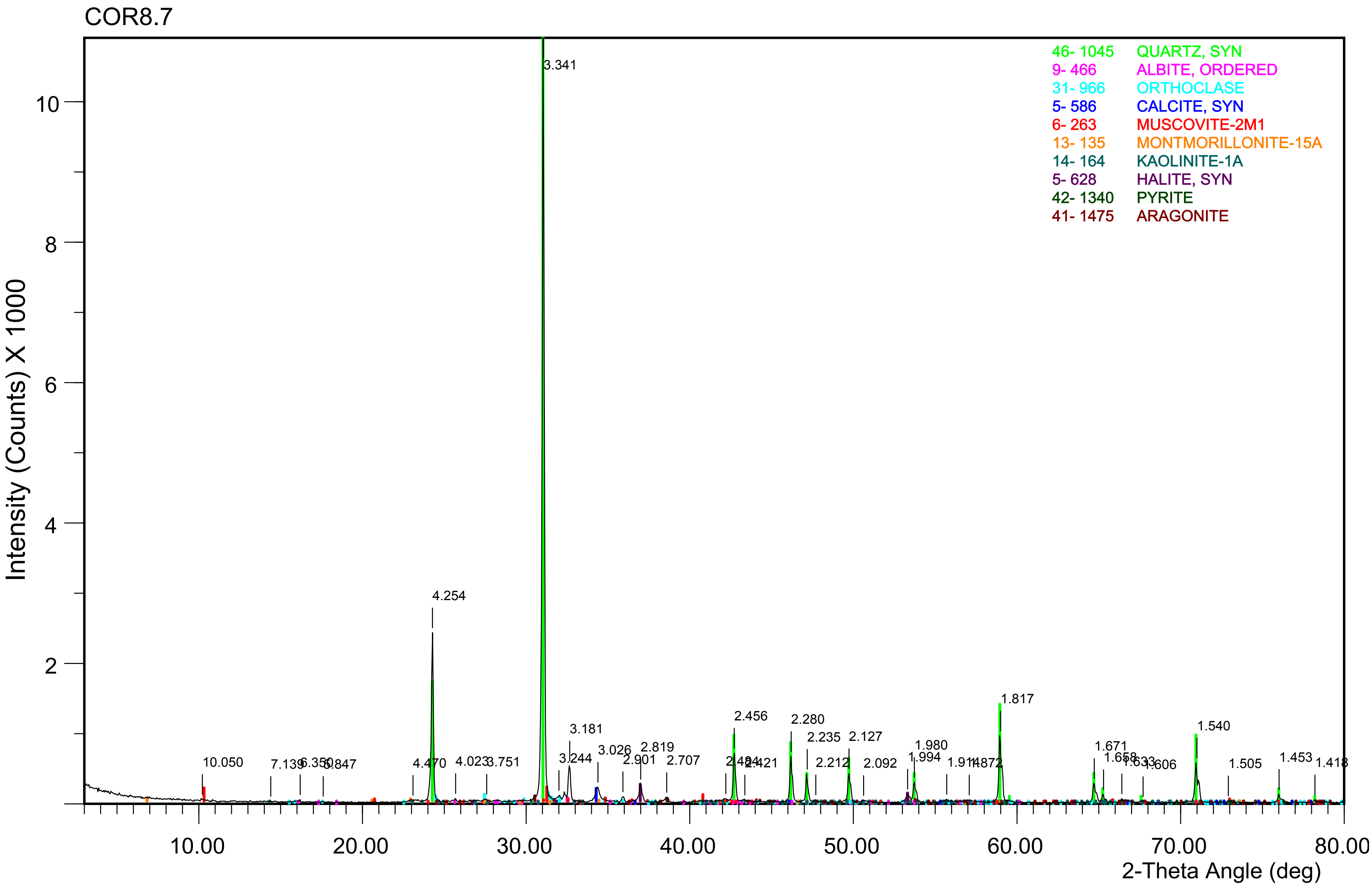

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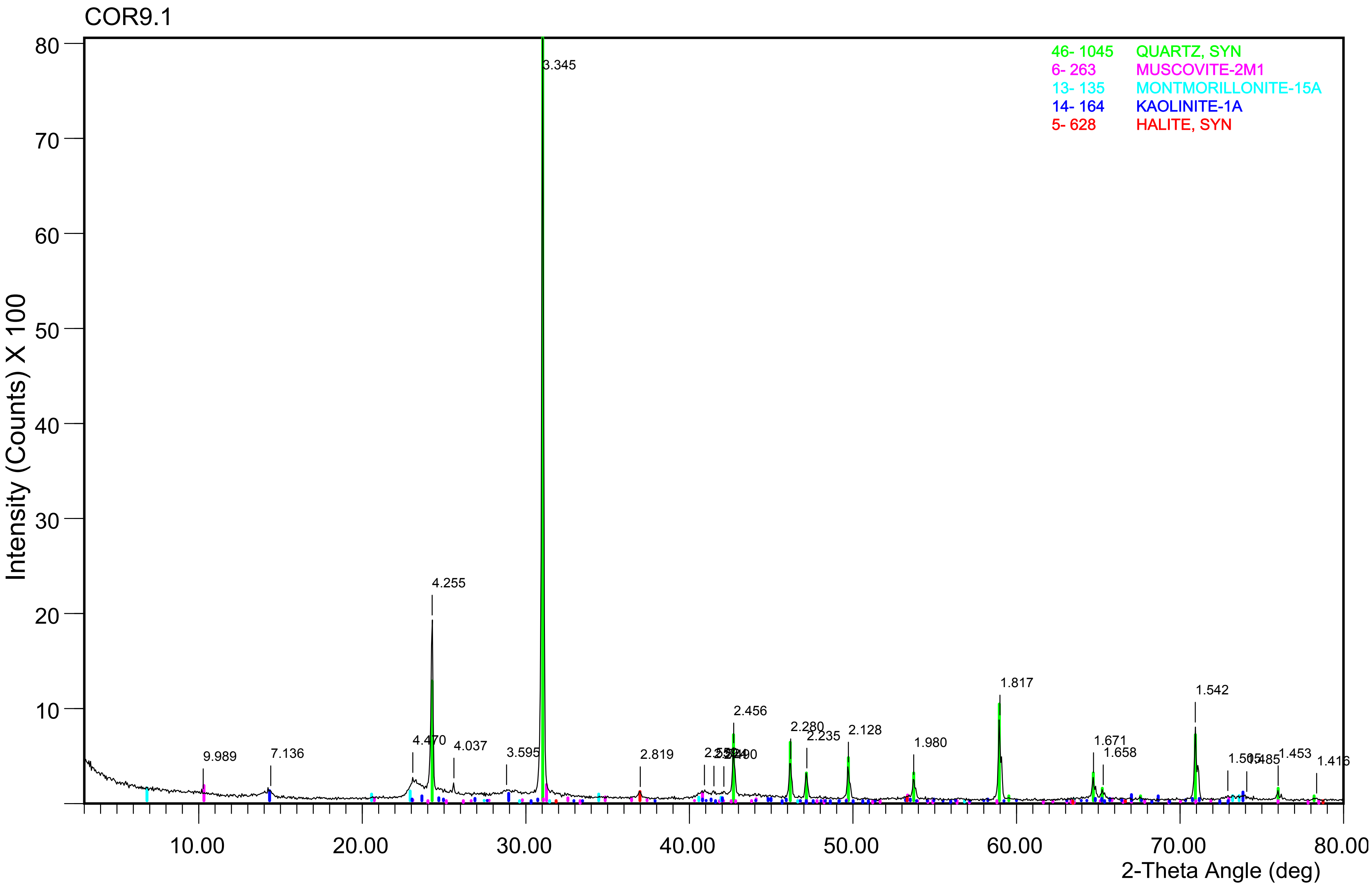
CSIRO Land and Water



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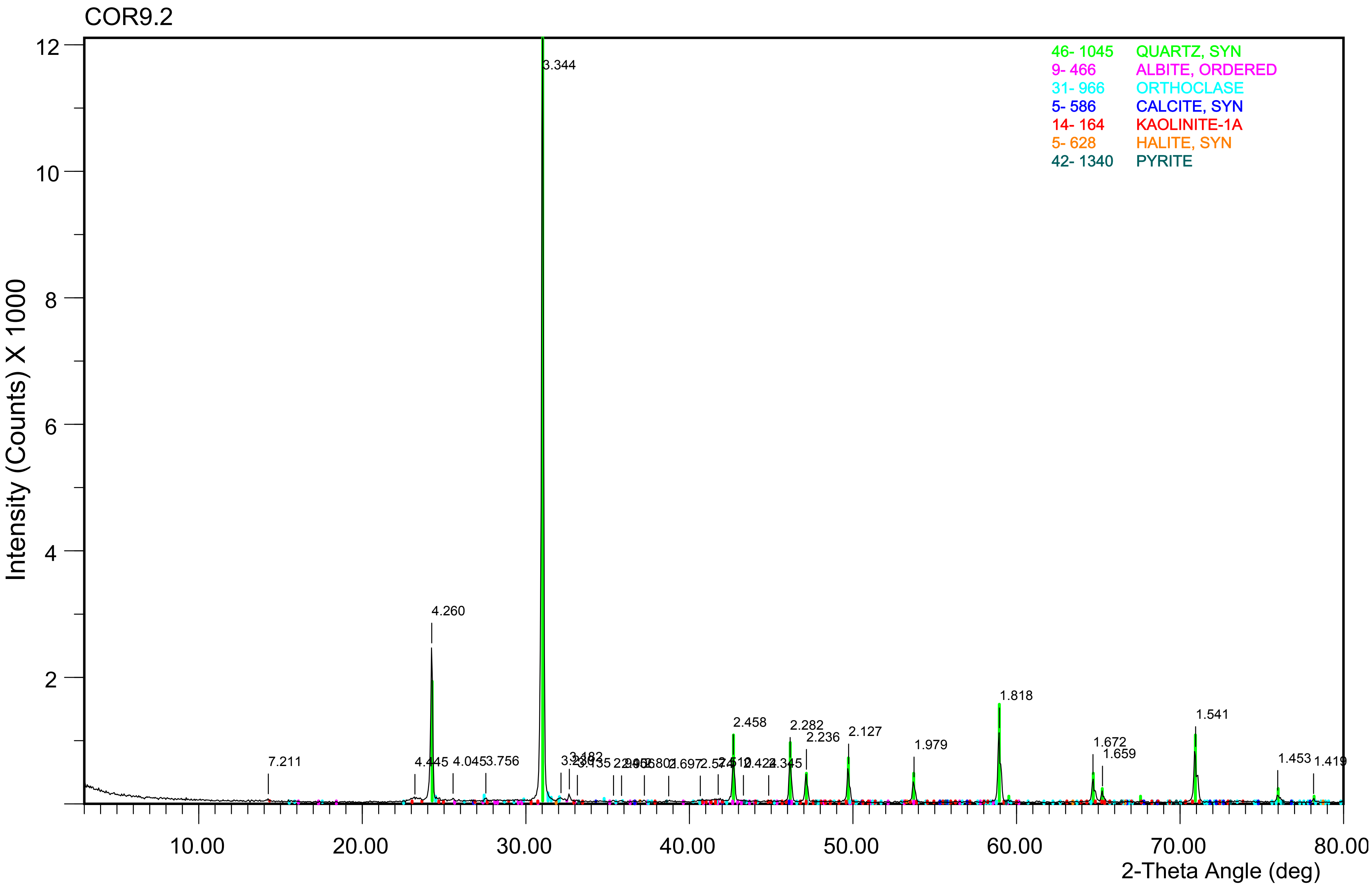

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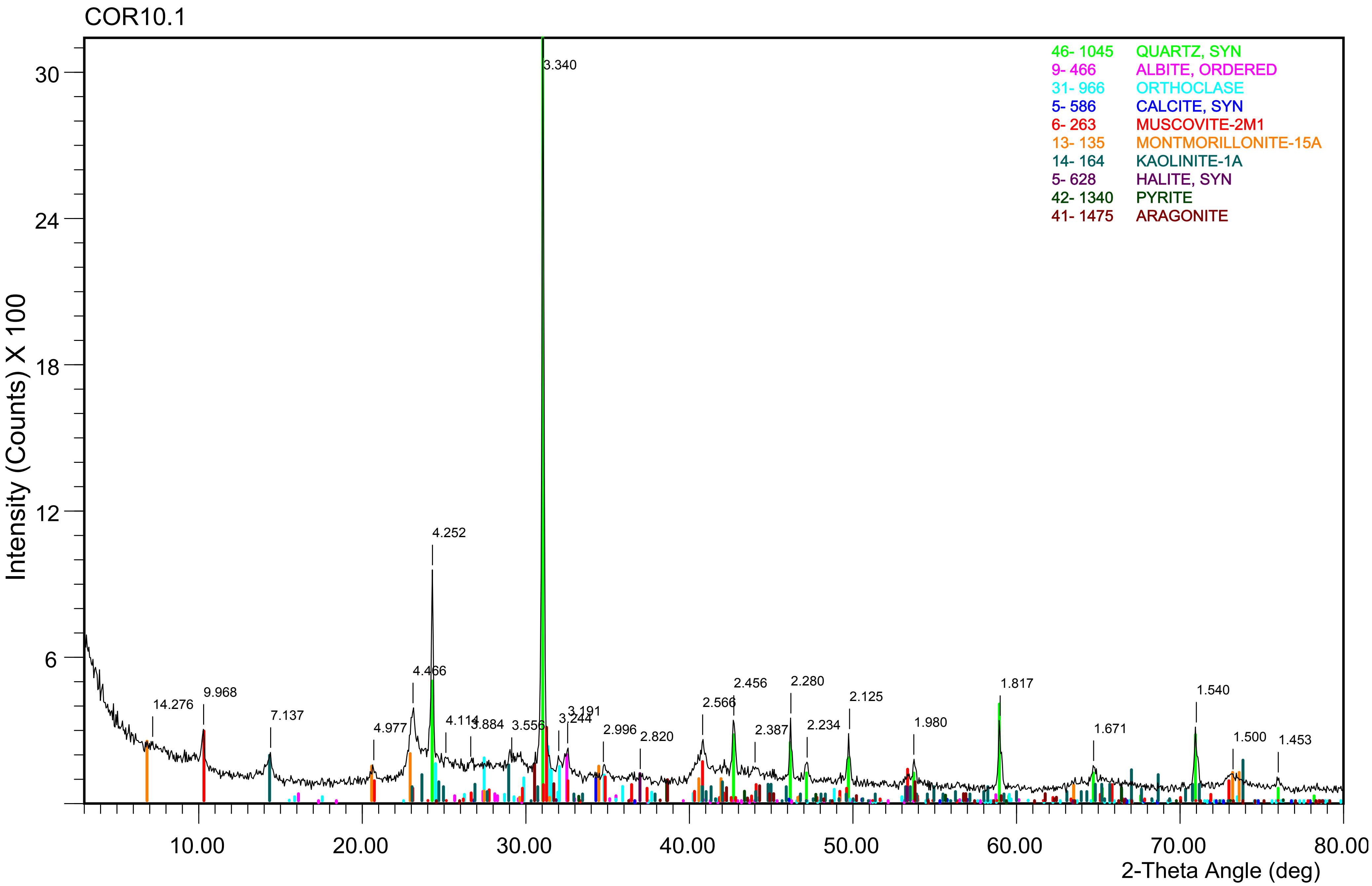

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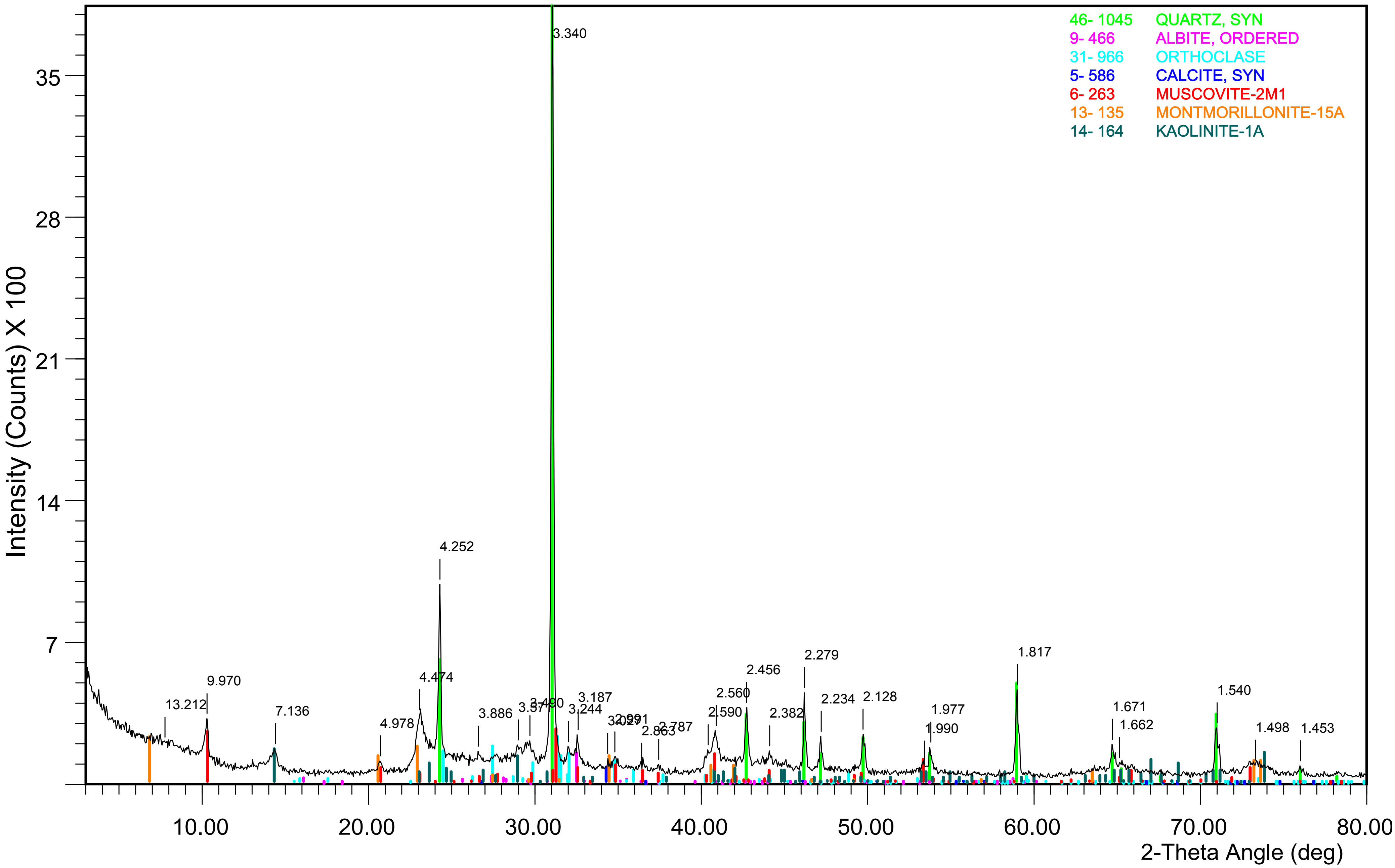
COR10.2



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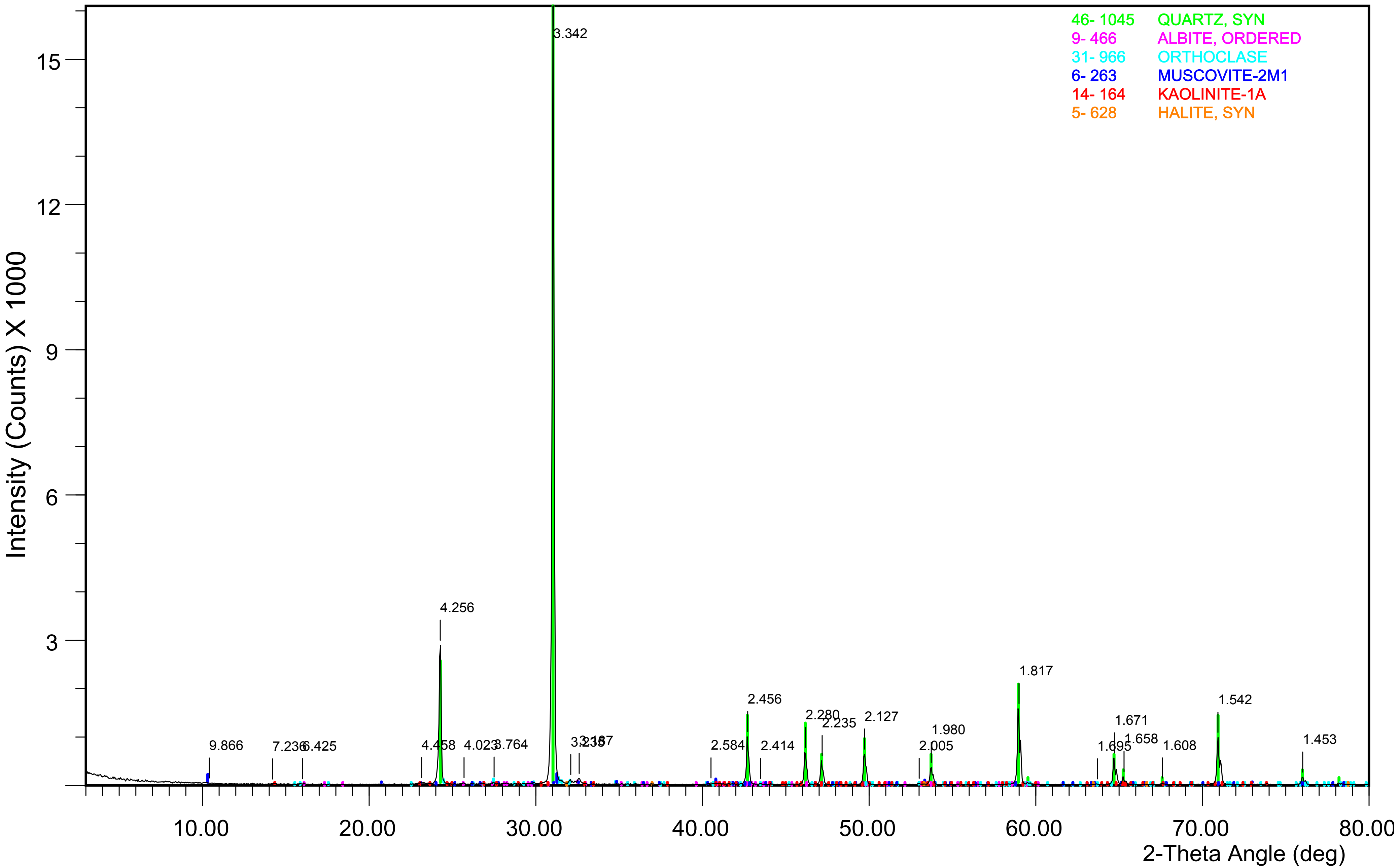
COR10.3



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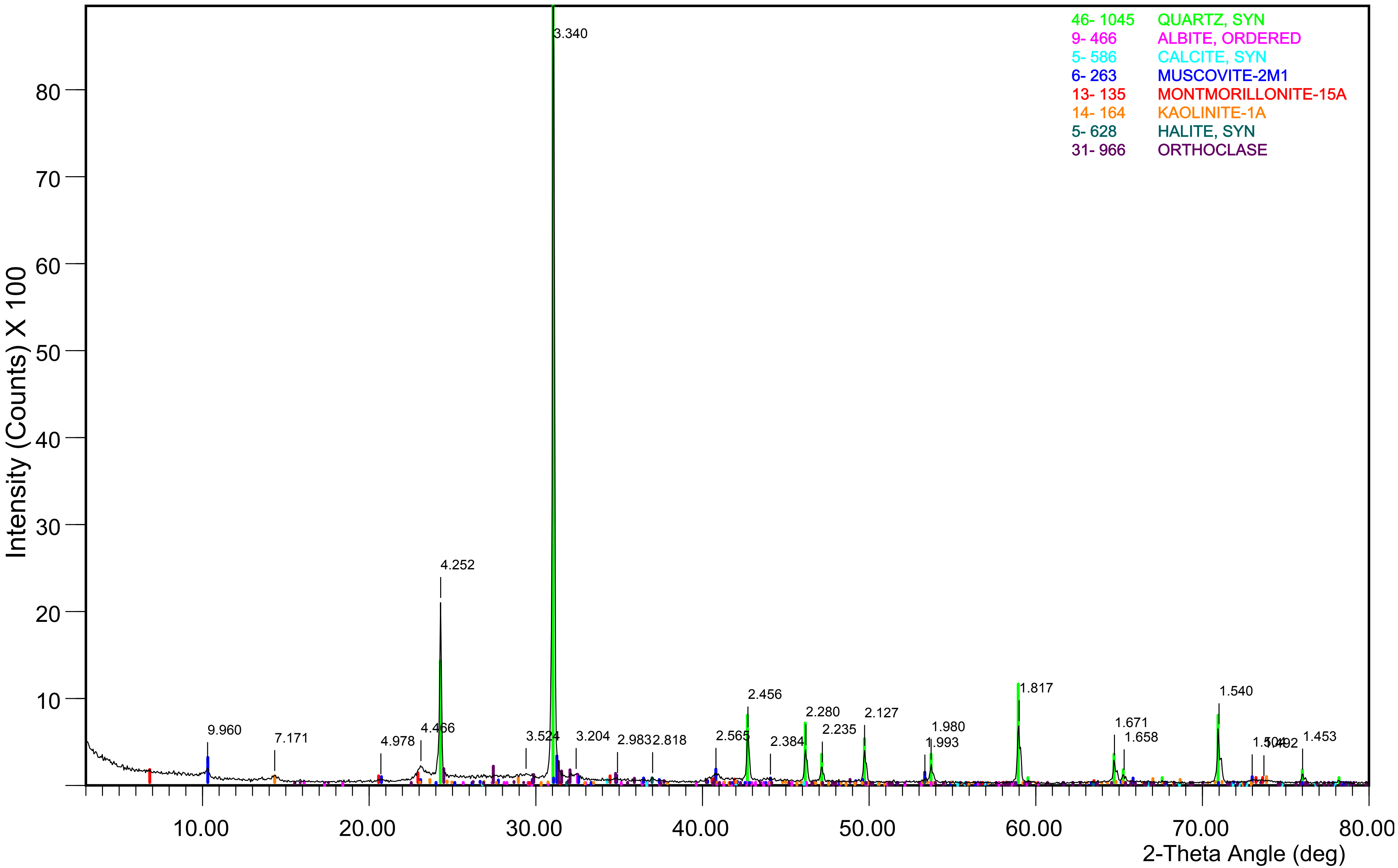
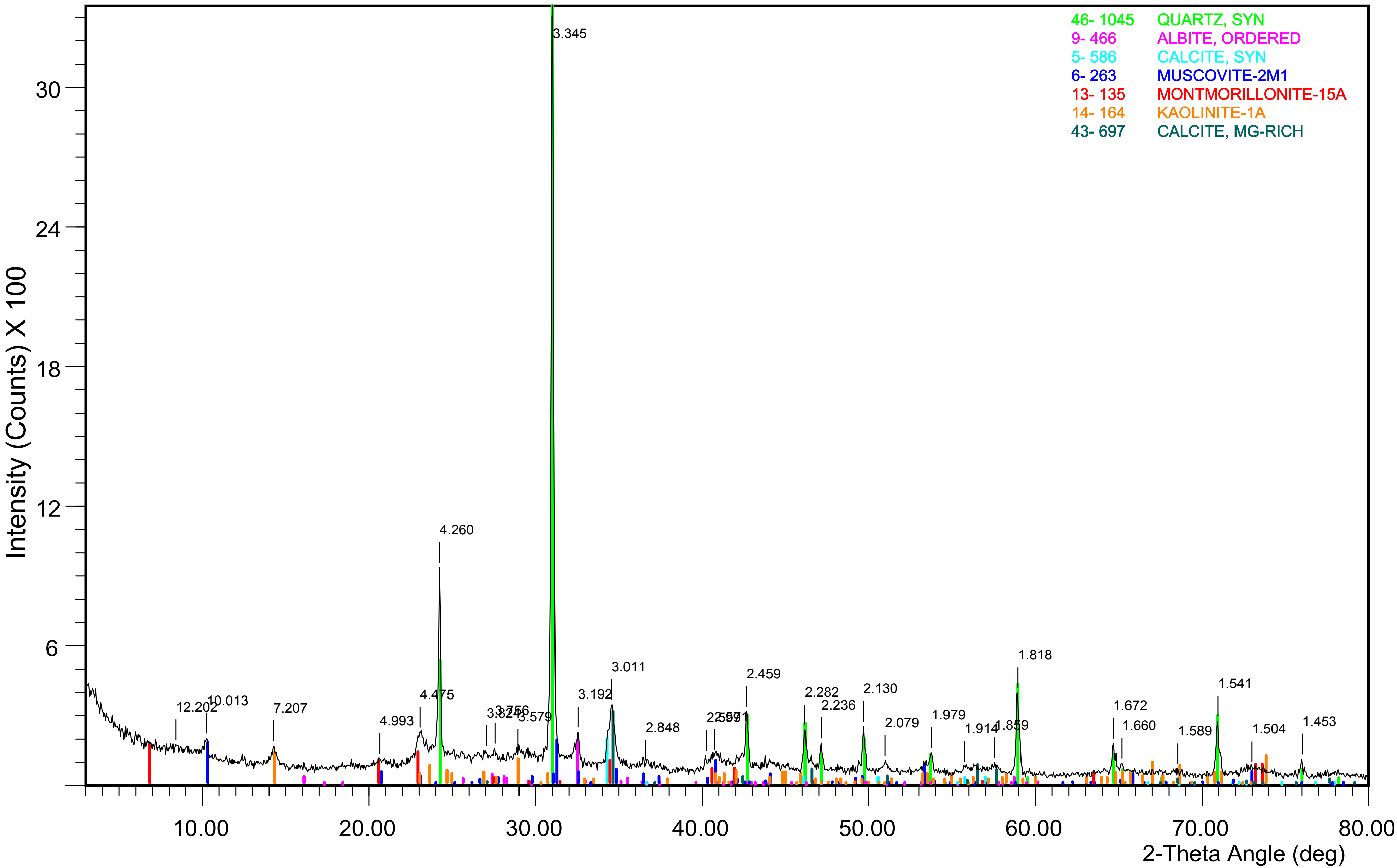
COR10.4



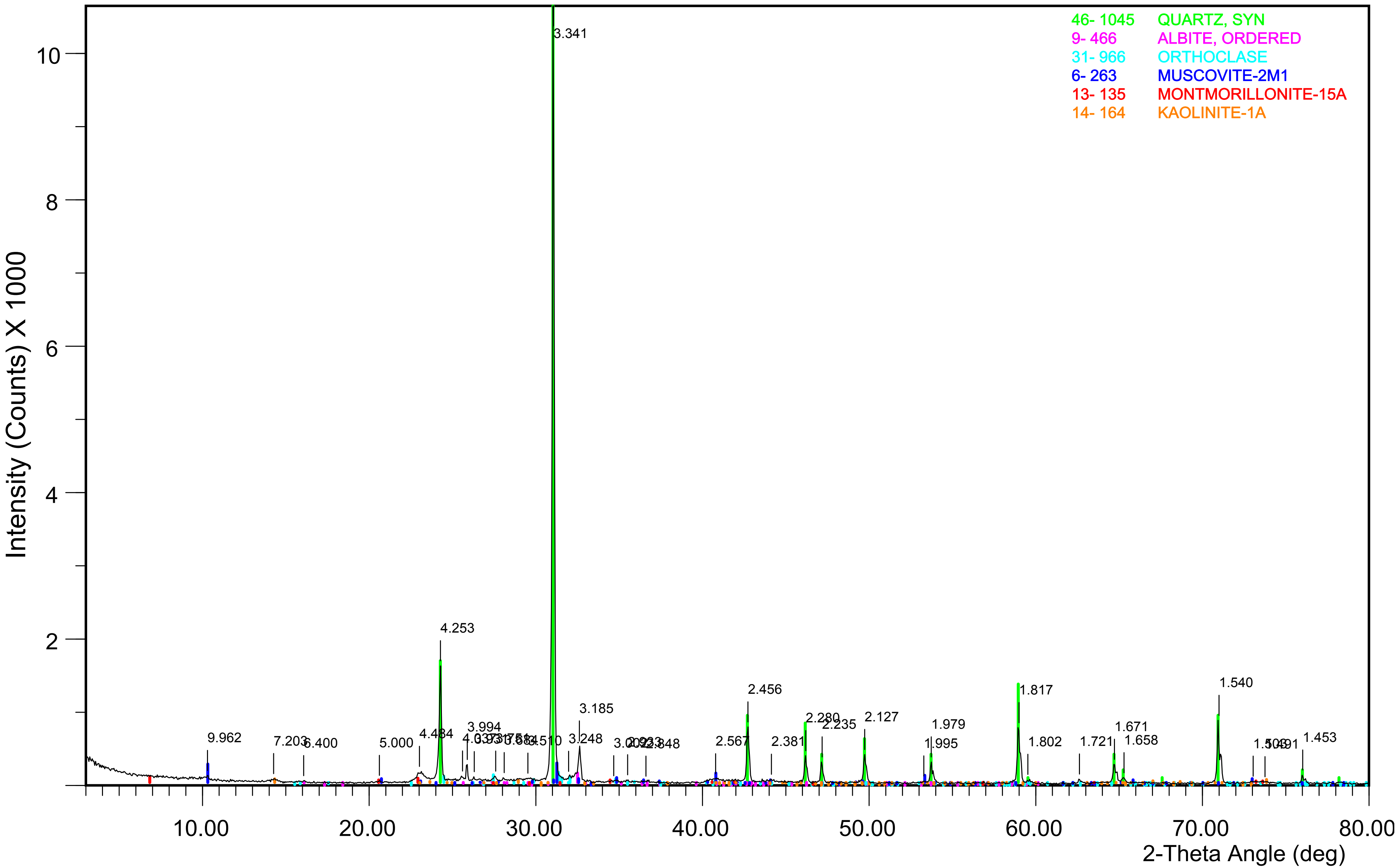
File Name: c:\...\17374blk.019

COR12.1



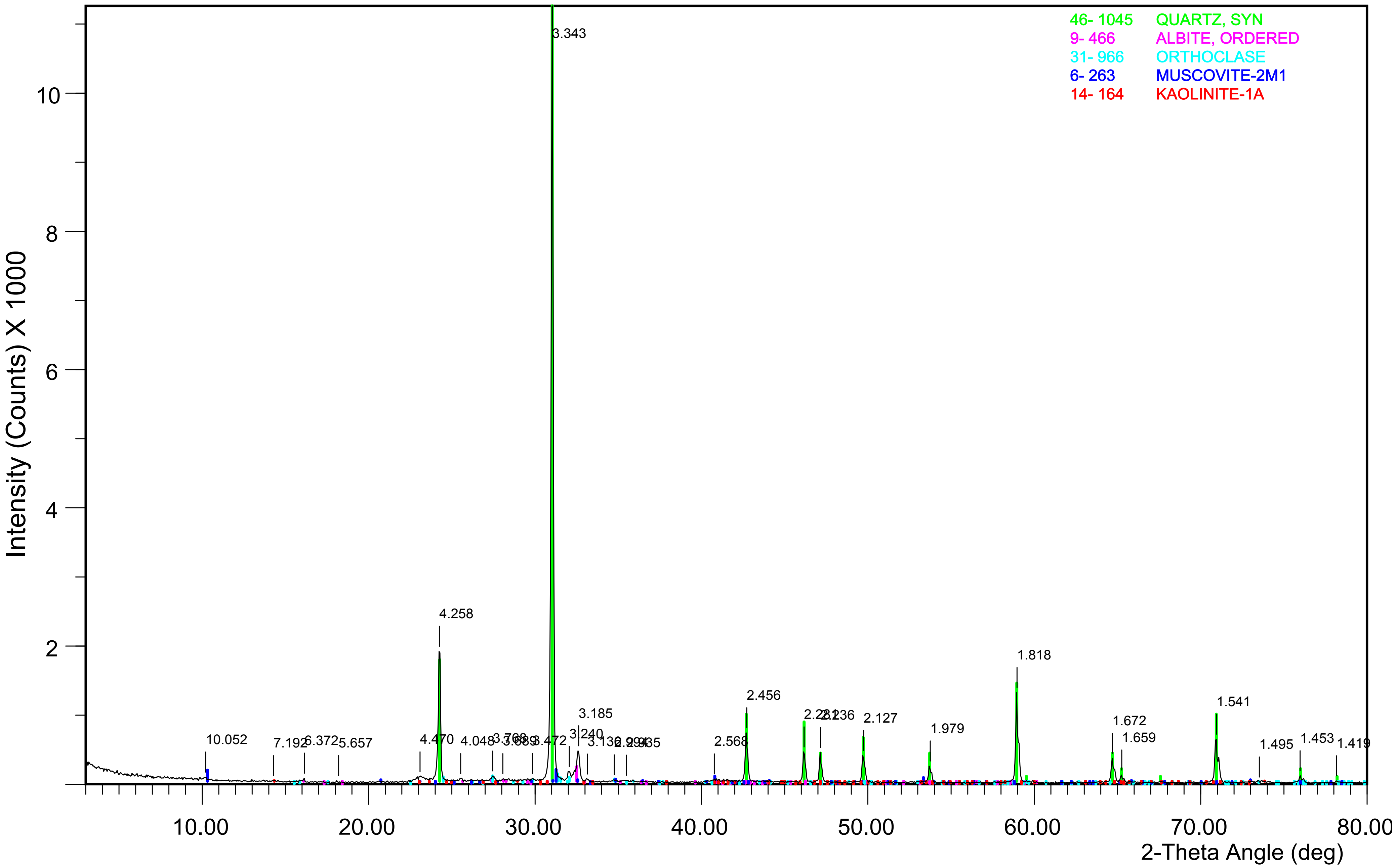
File Name: c:\...\17375blk.020

COR13.1



File Name: c:\...\17376blk.001

COR13.2



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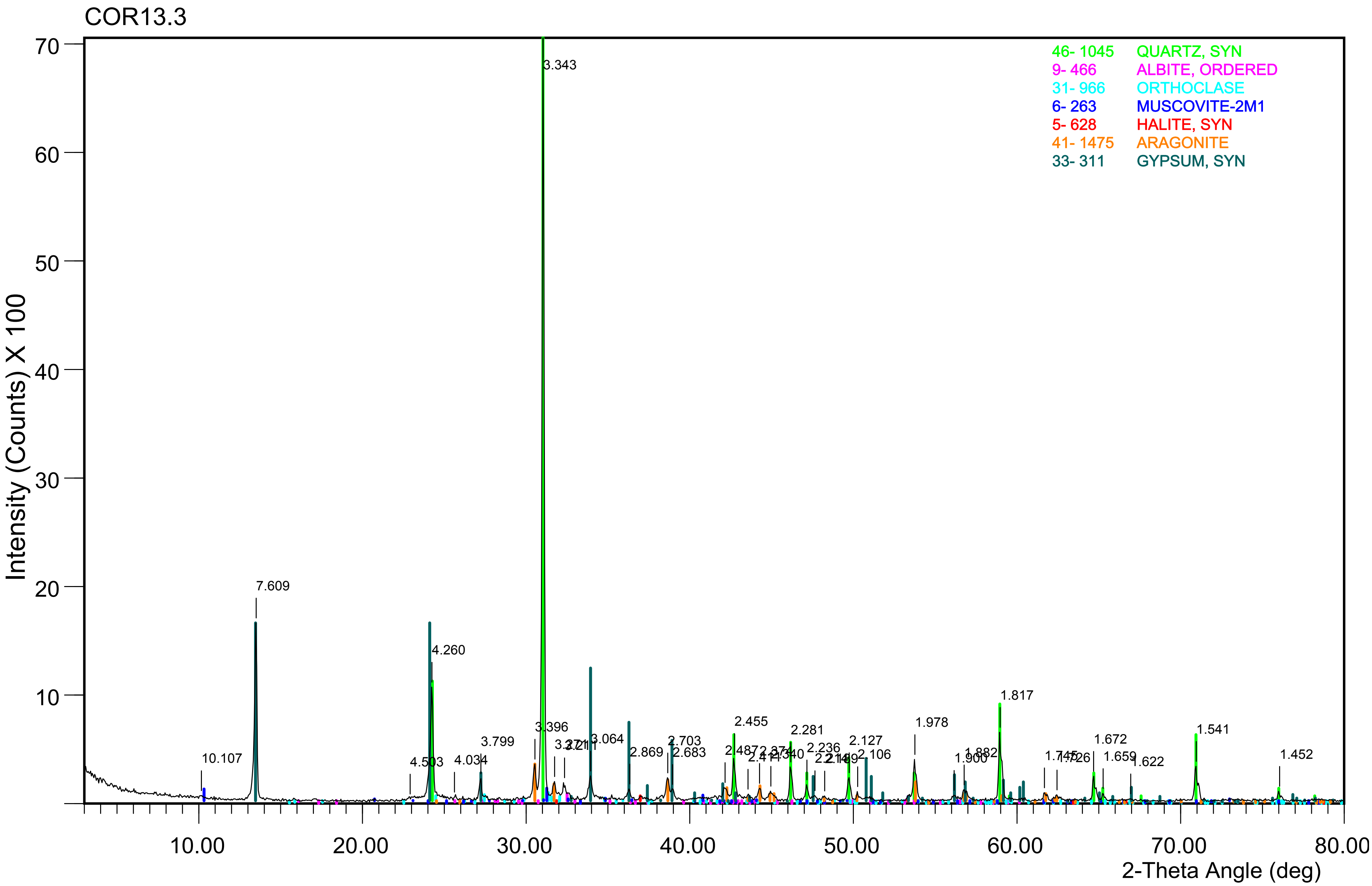
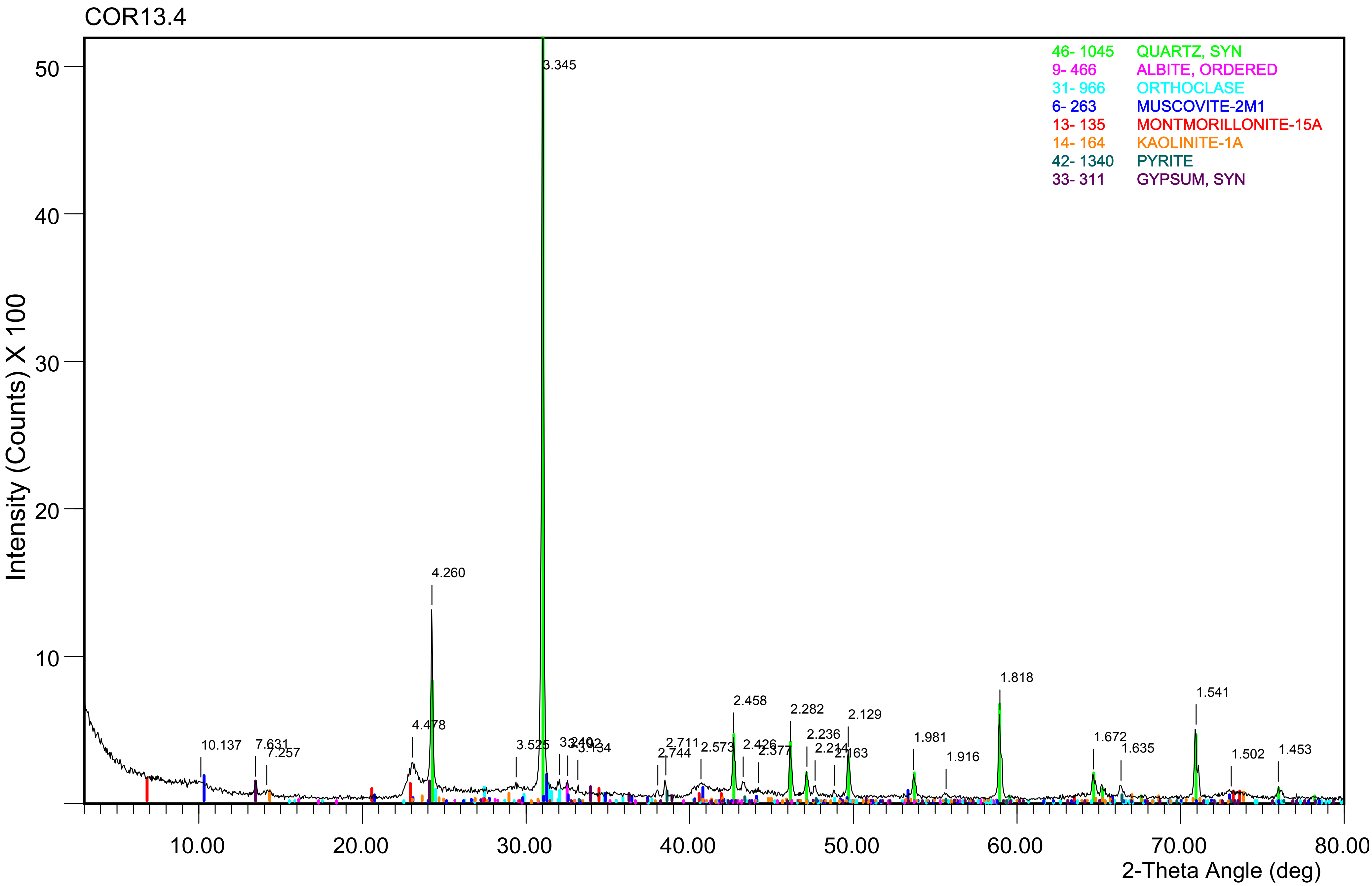


File Name: c:\...\17378blk.003



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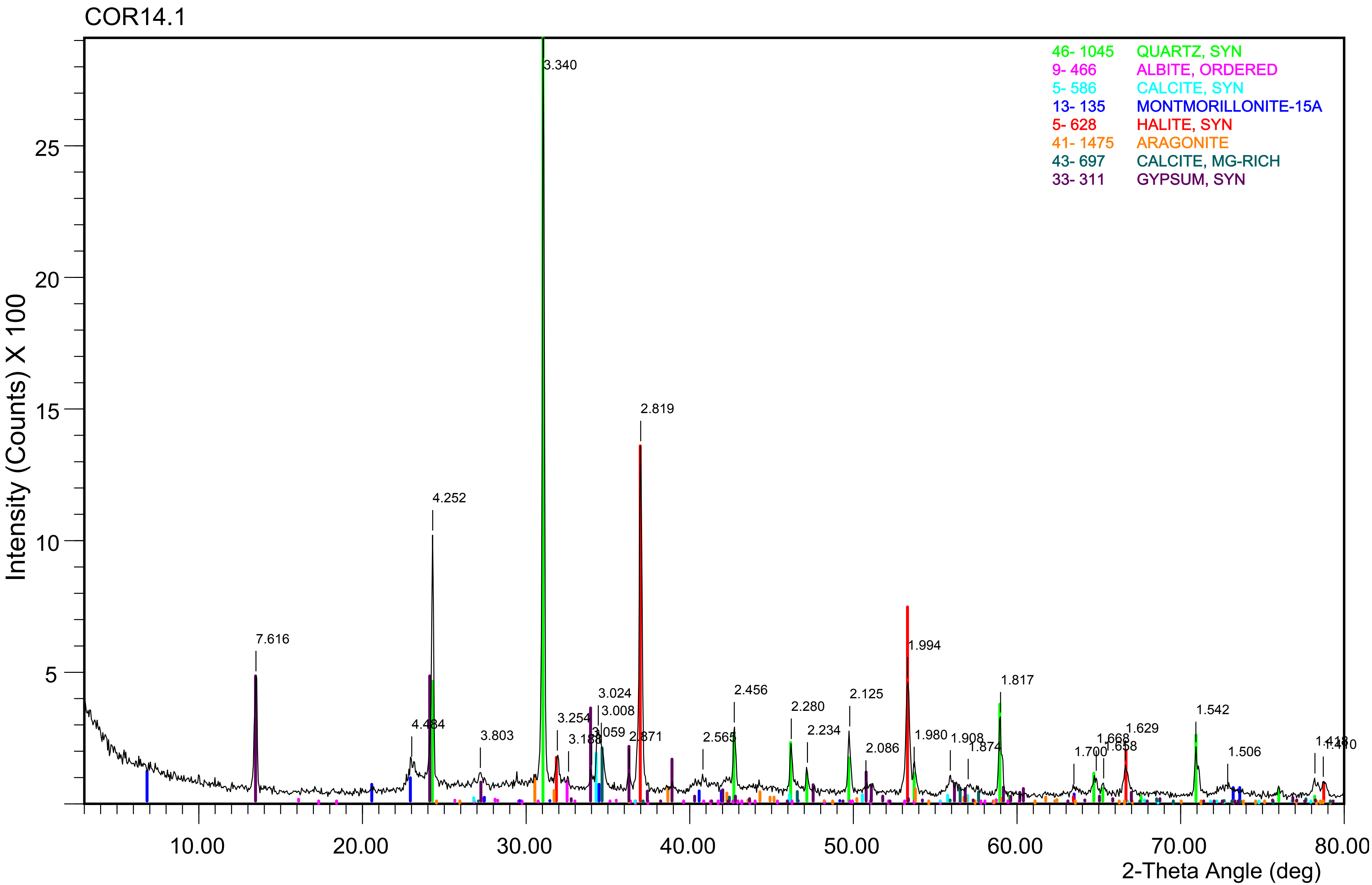

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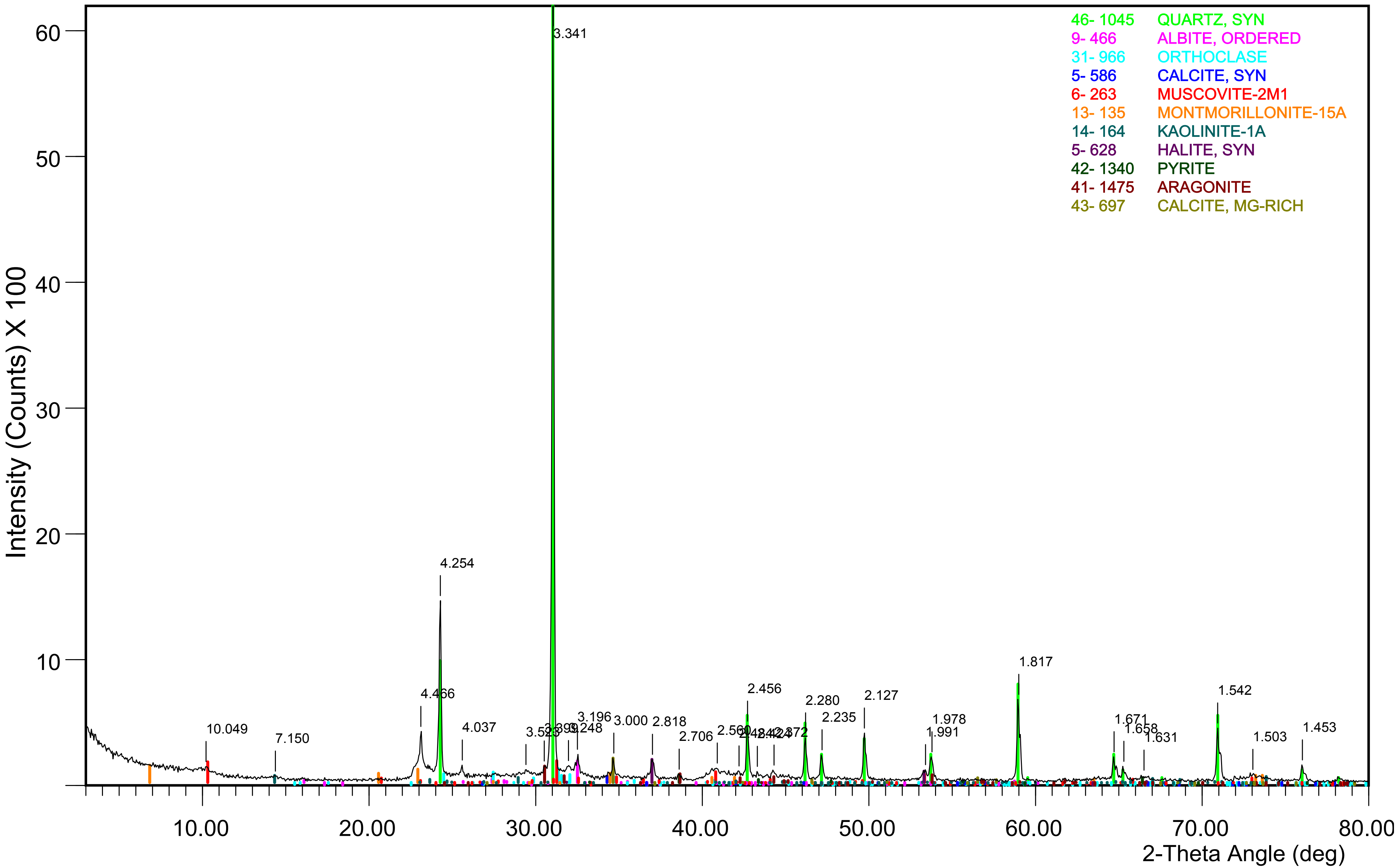
COR14.2



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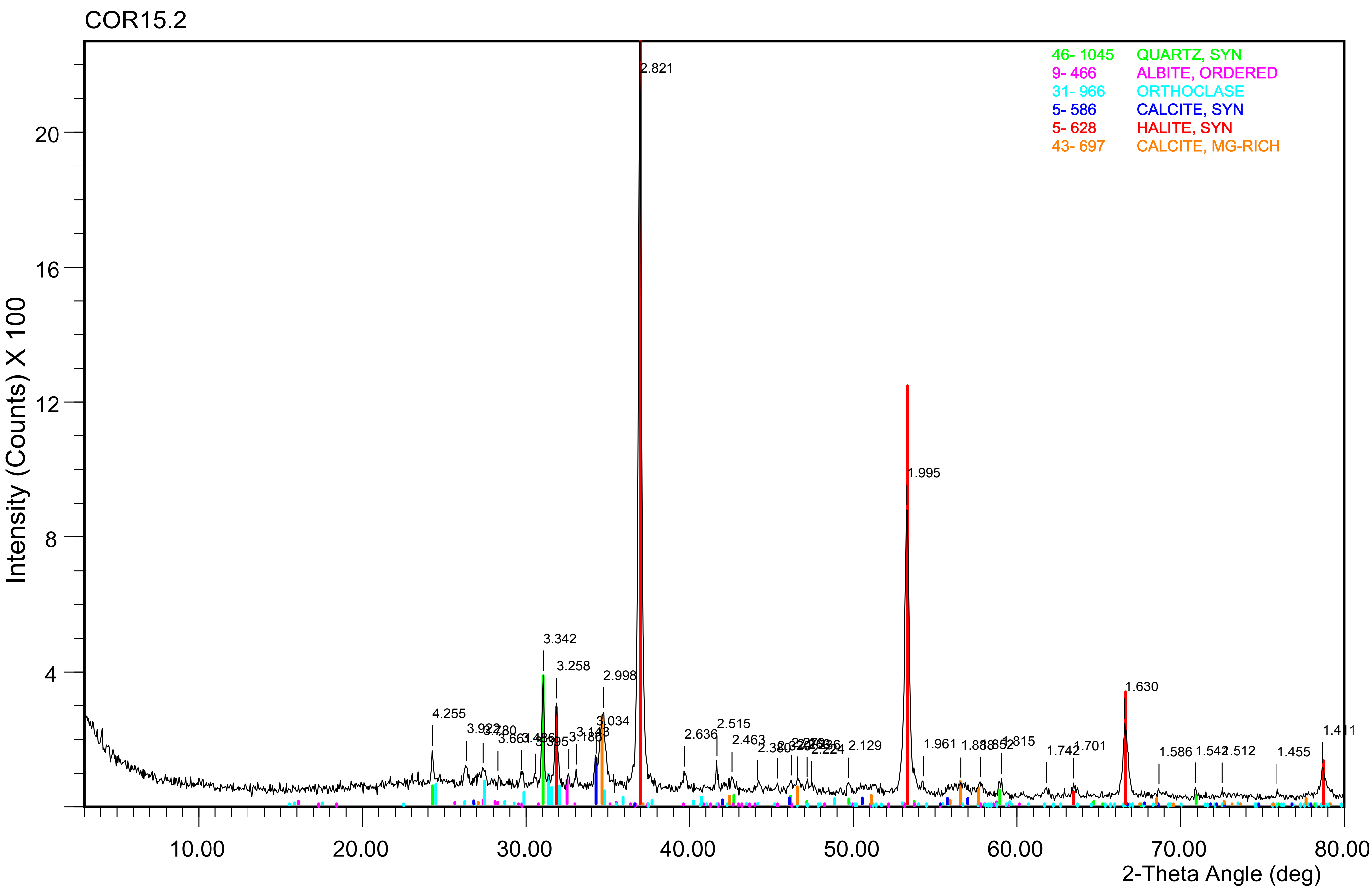

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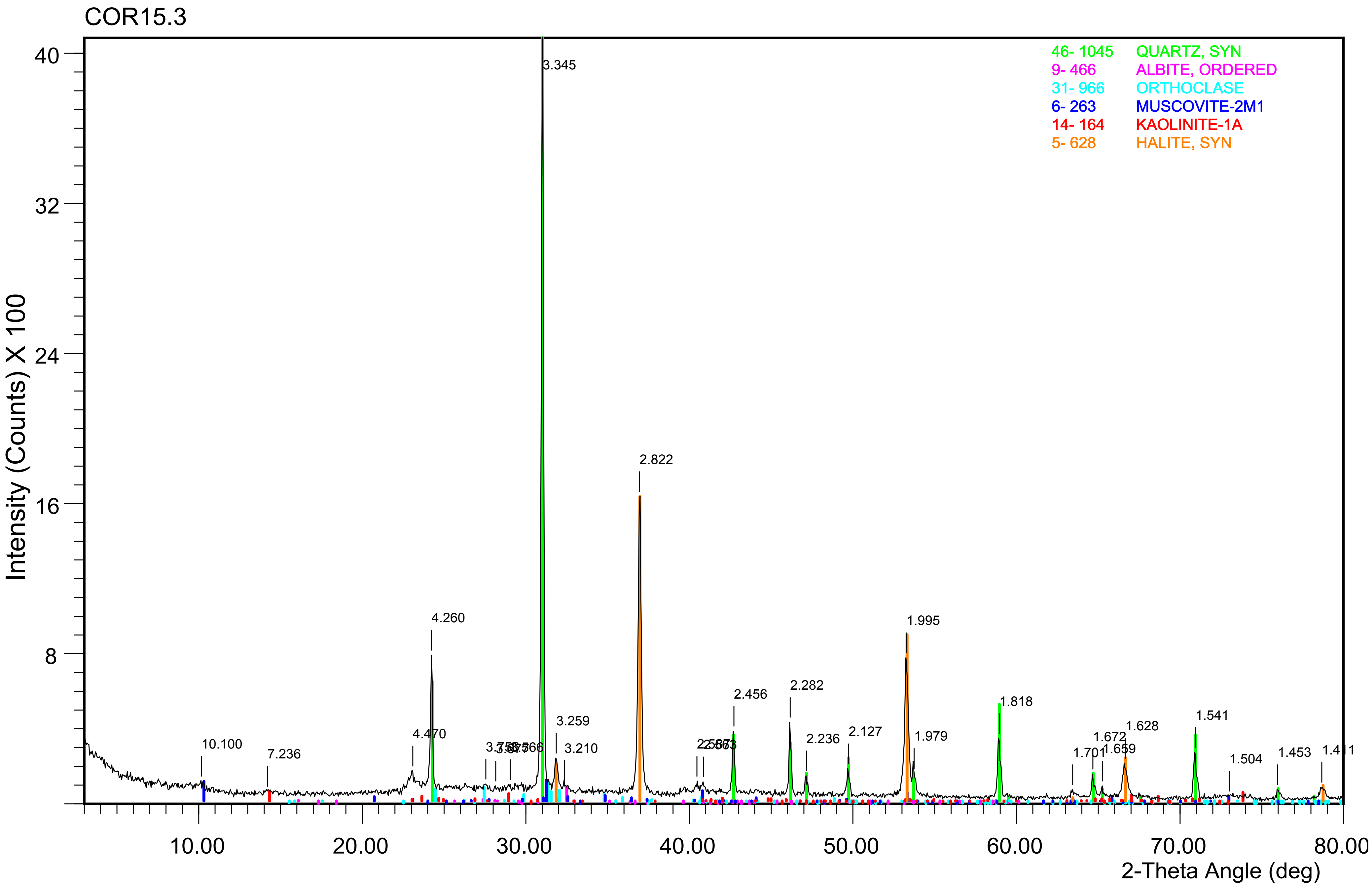

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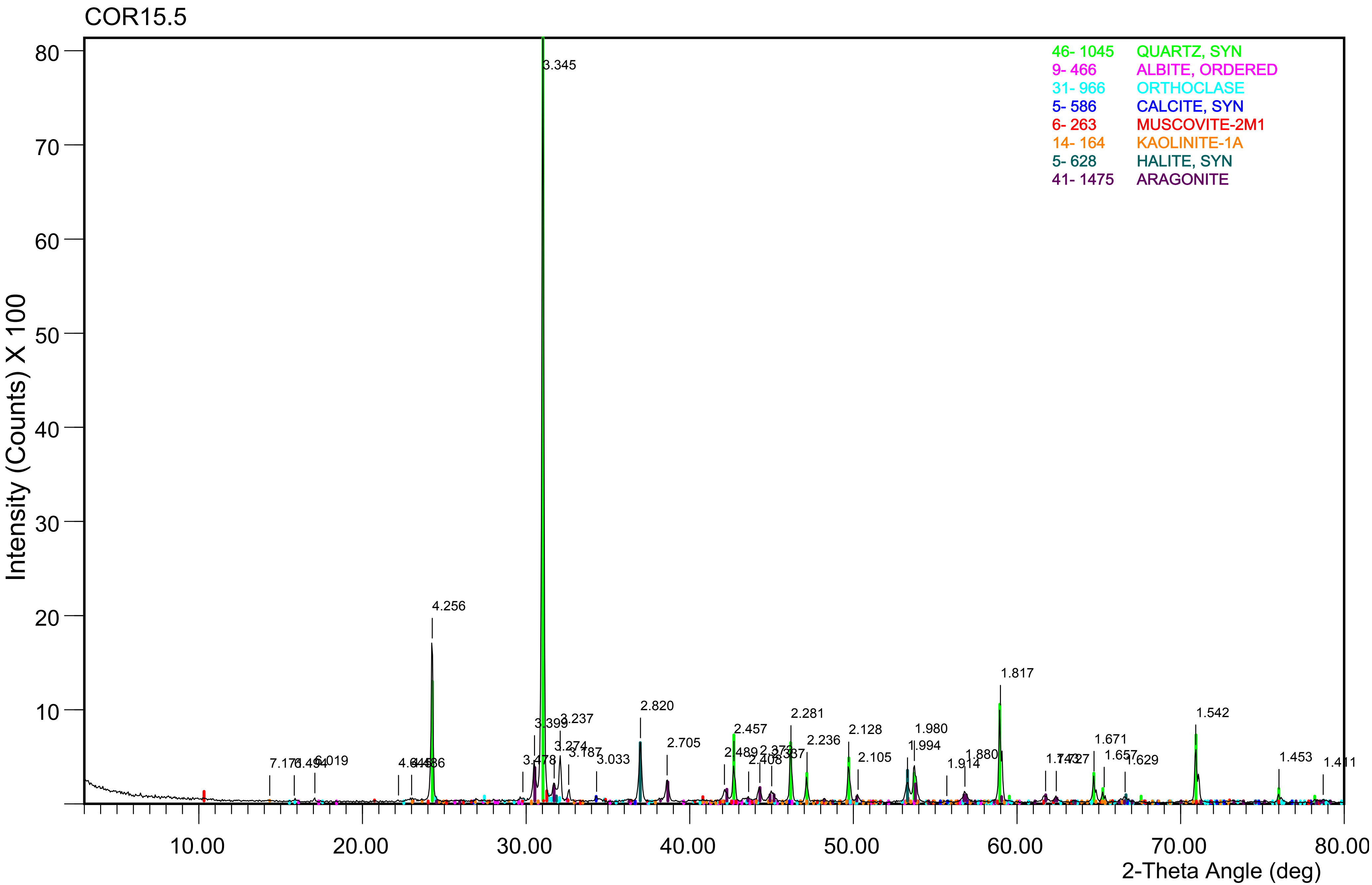
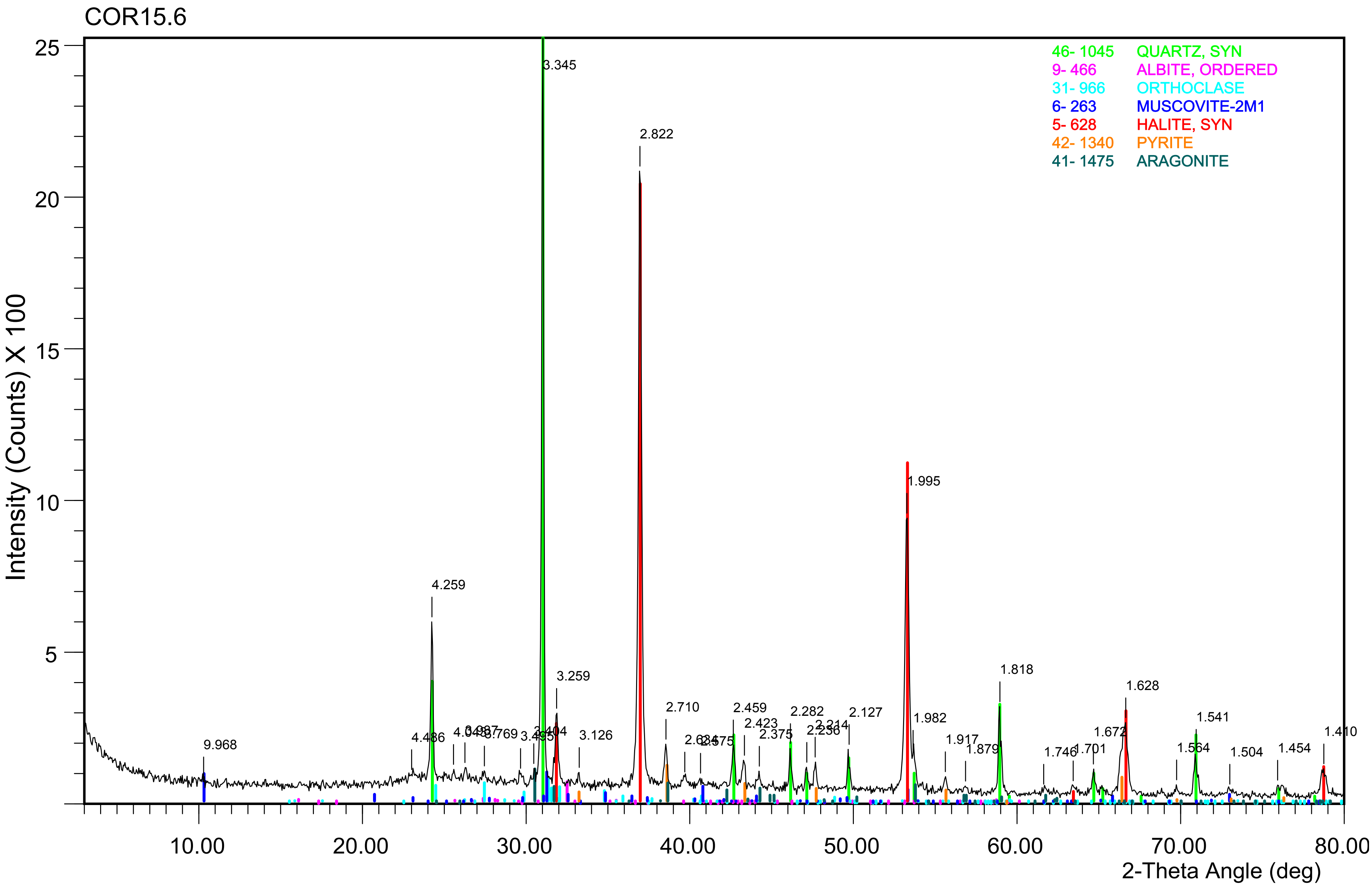


File Name: c:\...\17384blk.009



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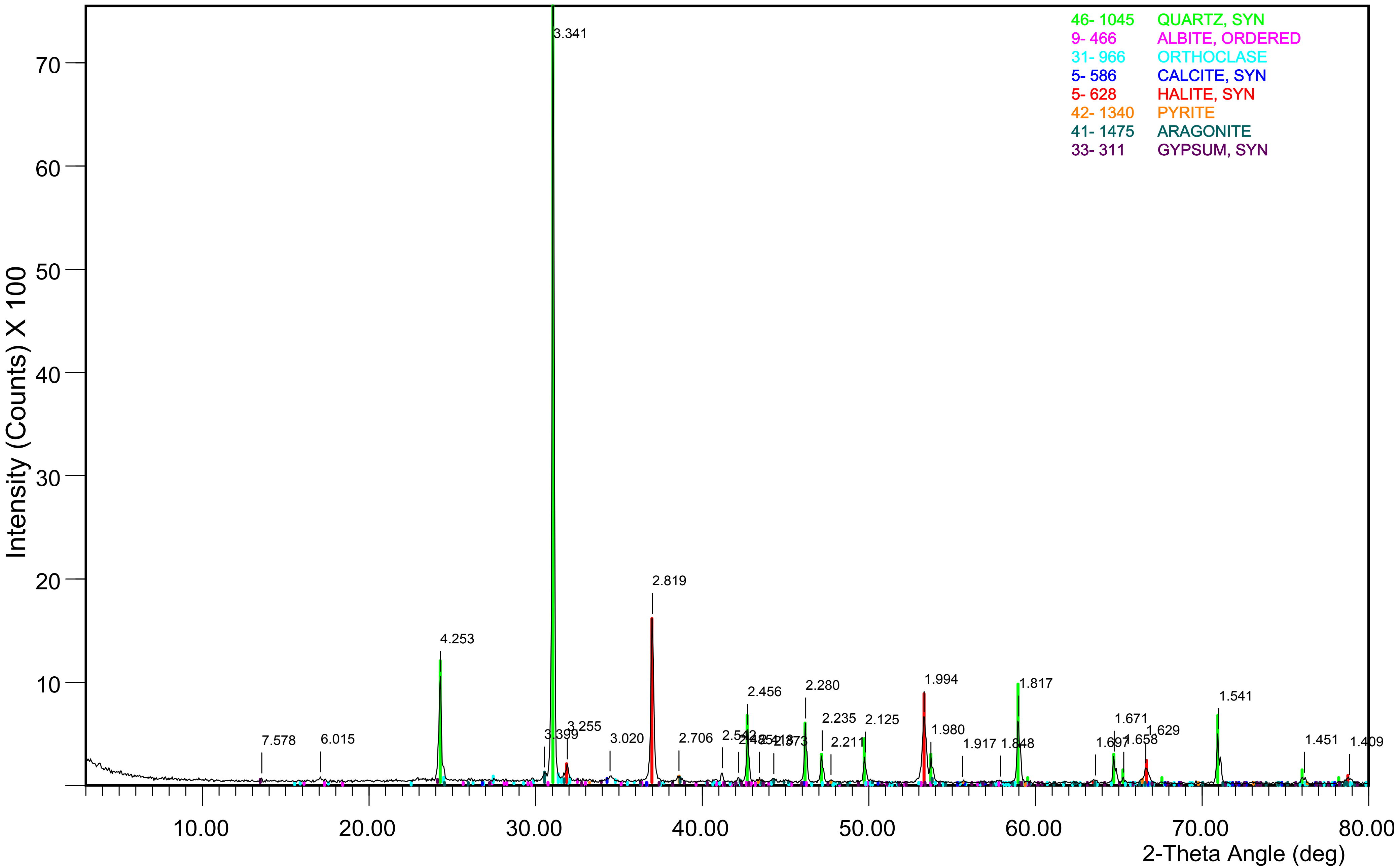
COR15.7



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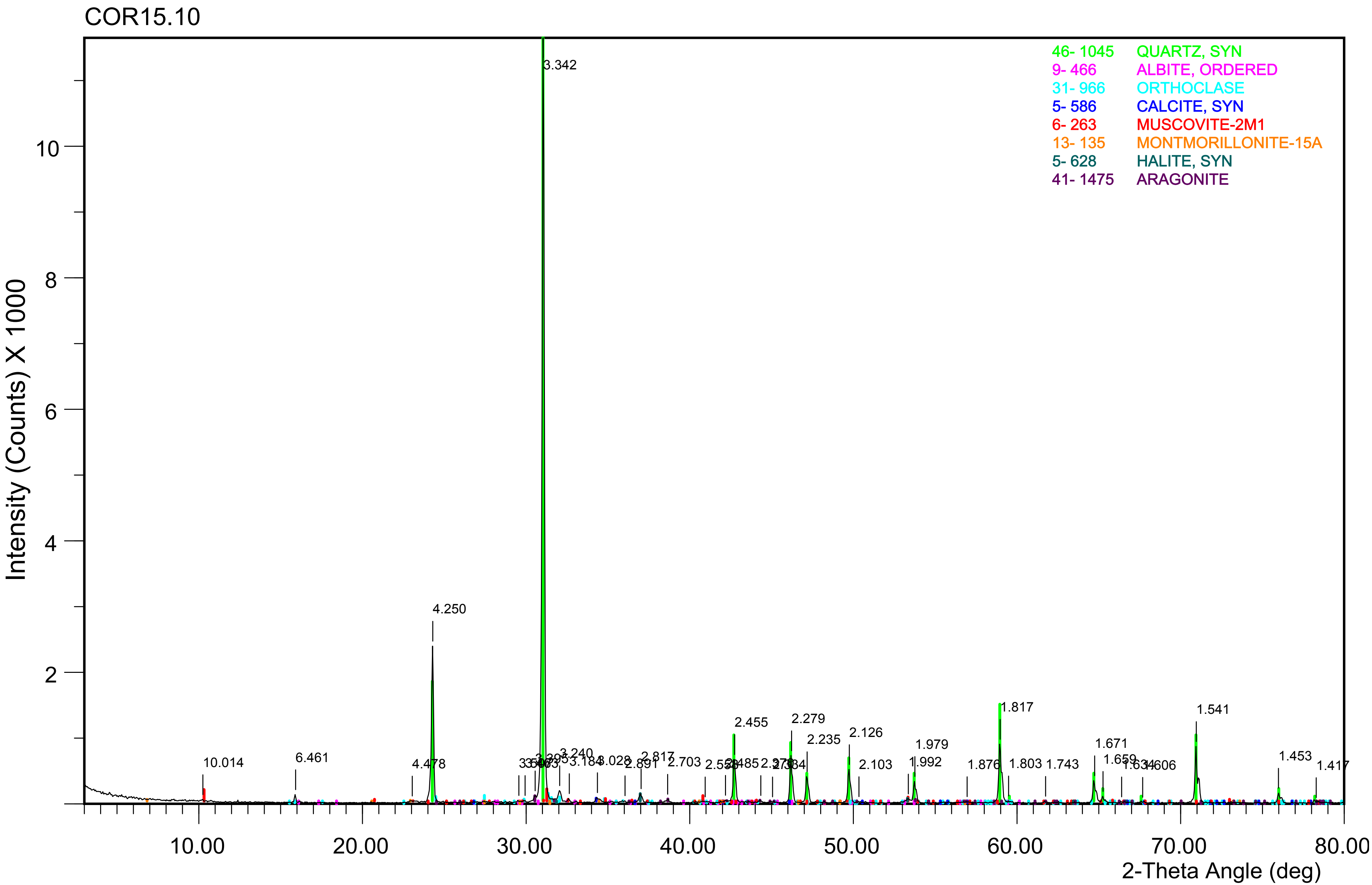

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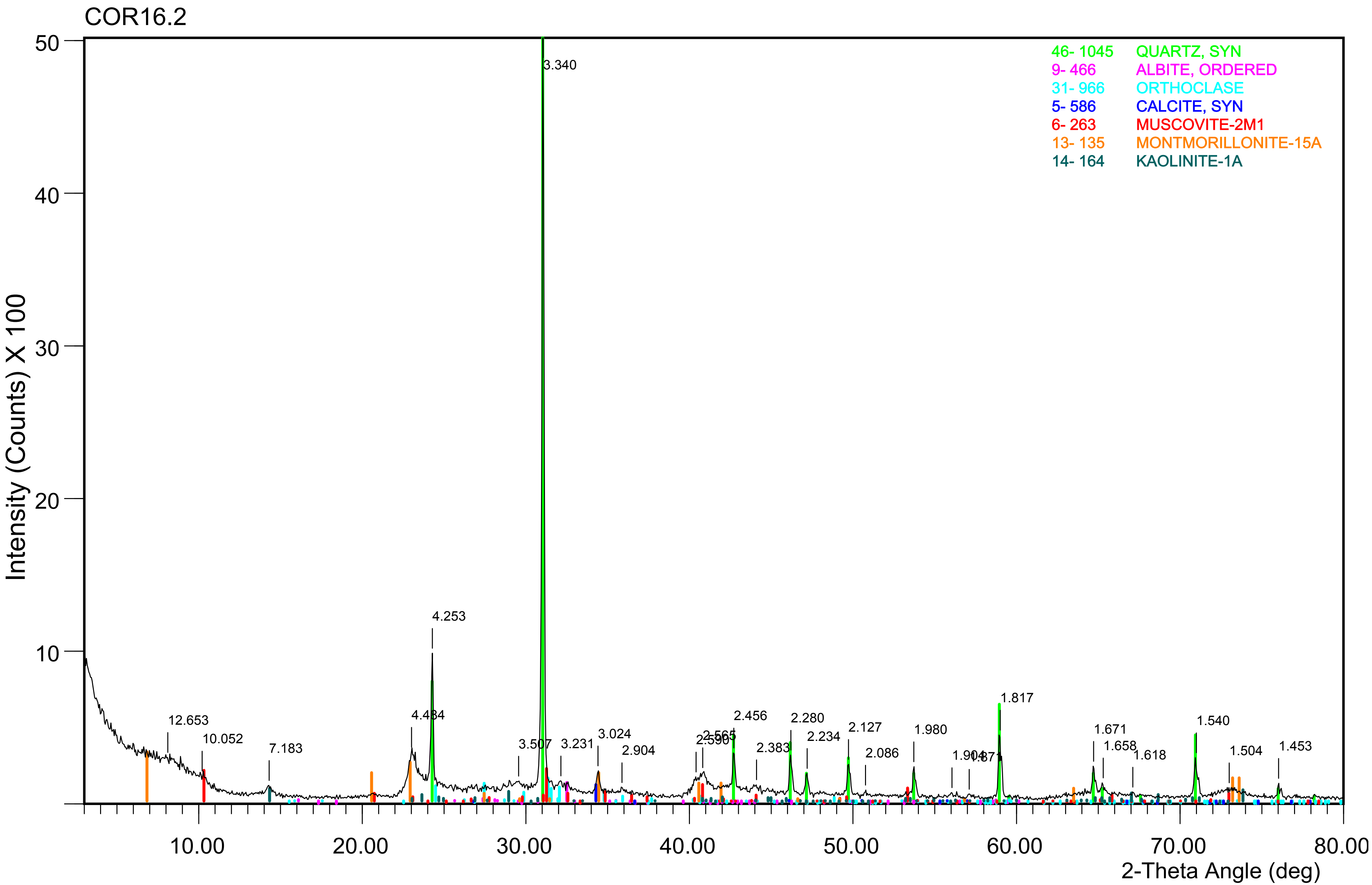

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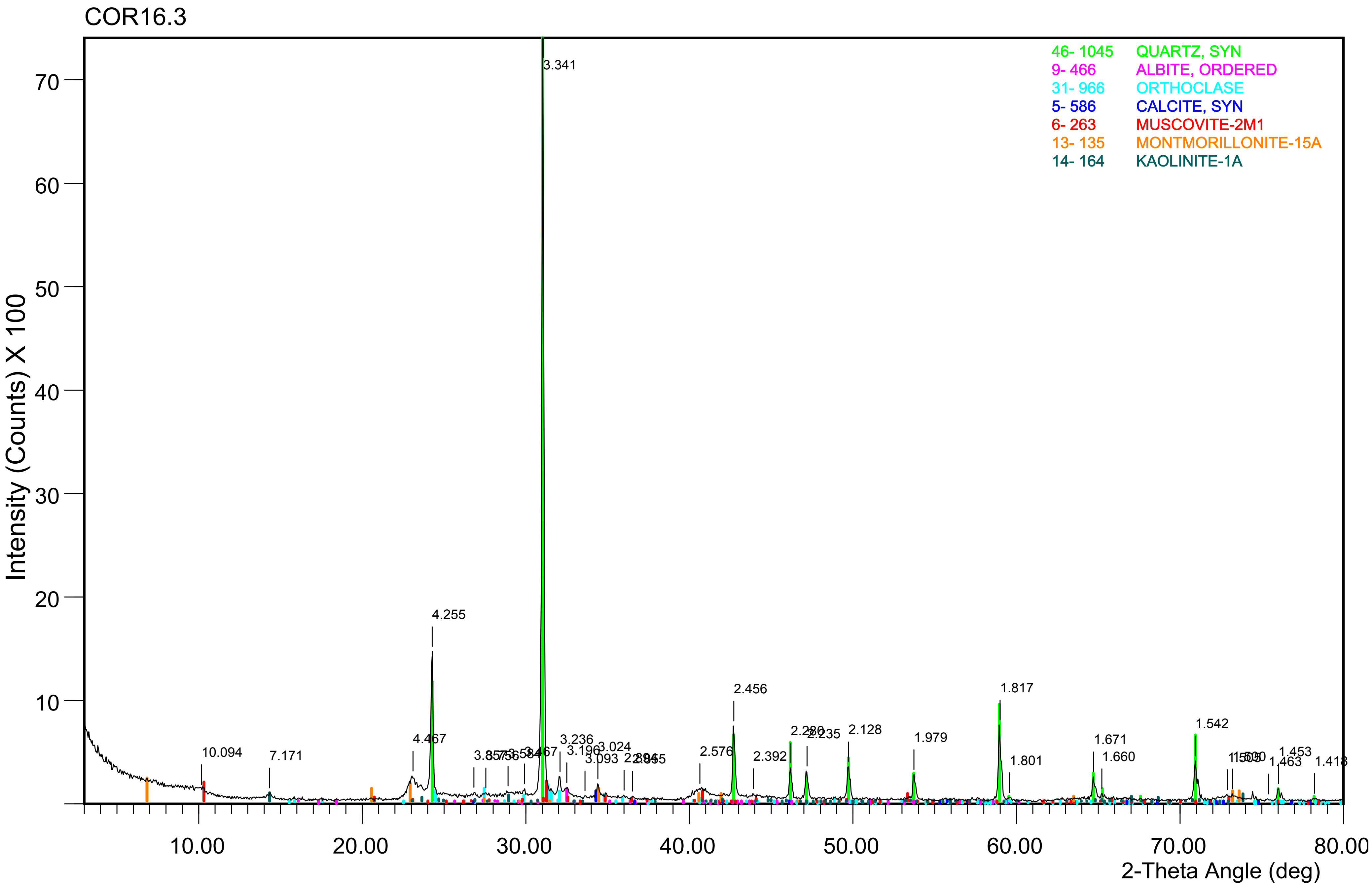
CSIRO Land and Water



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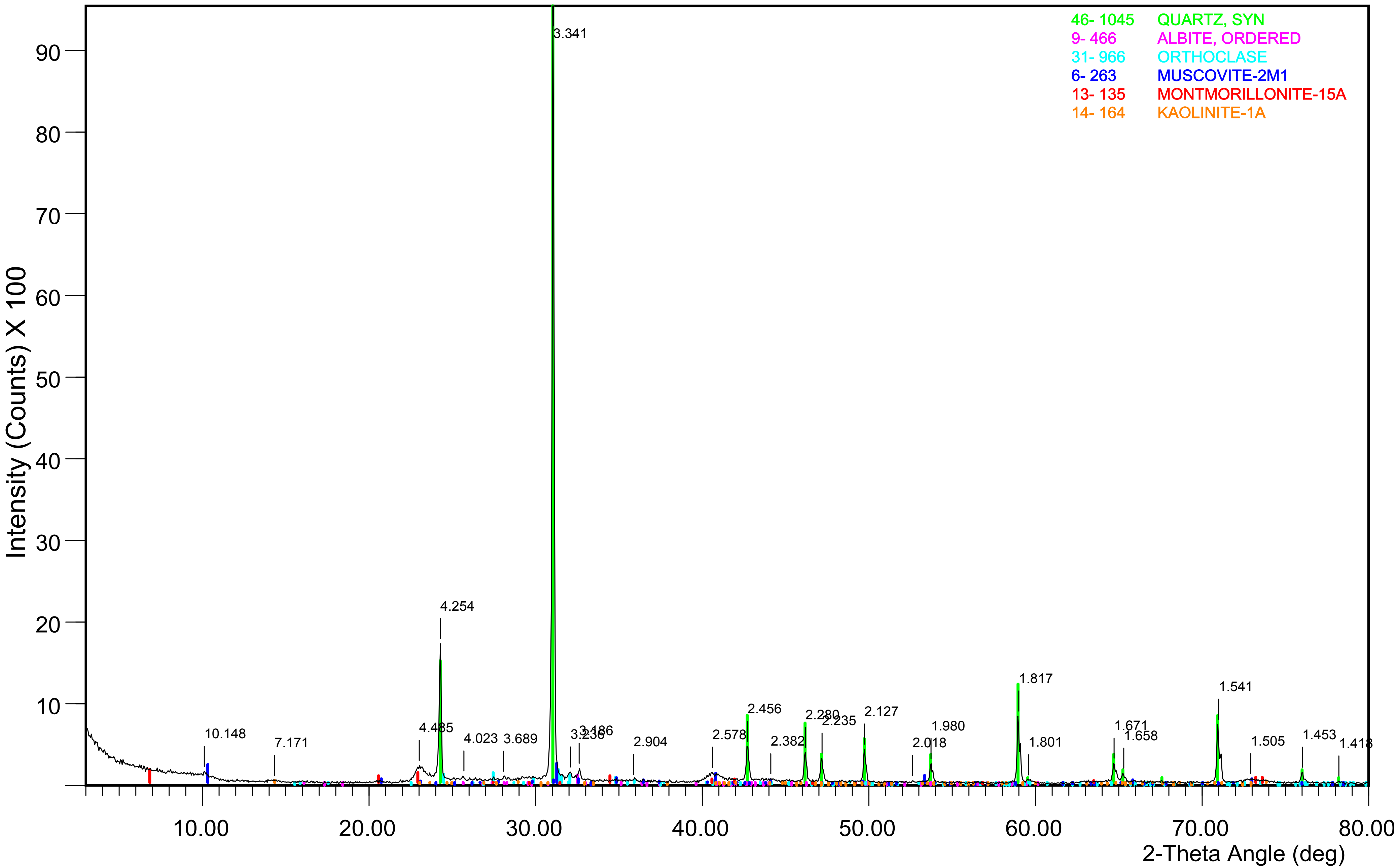
COR16.4



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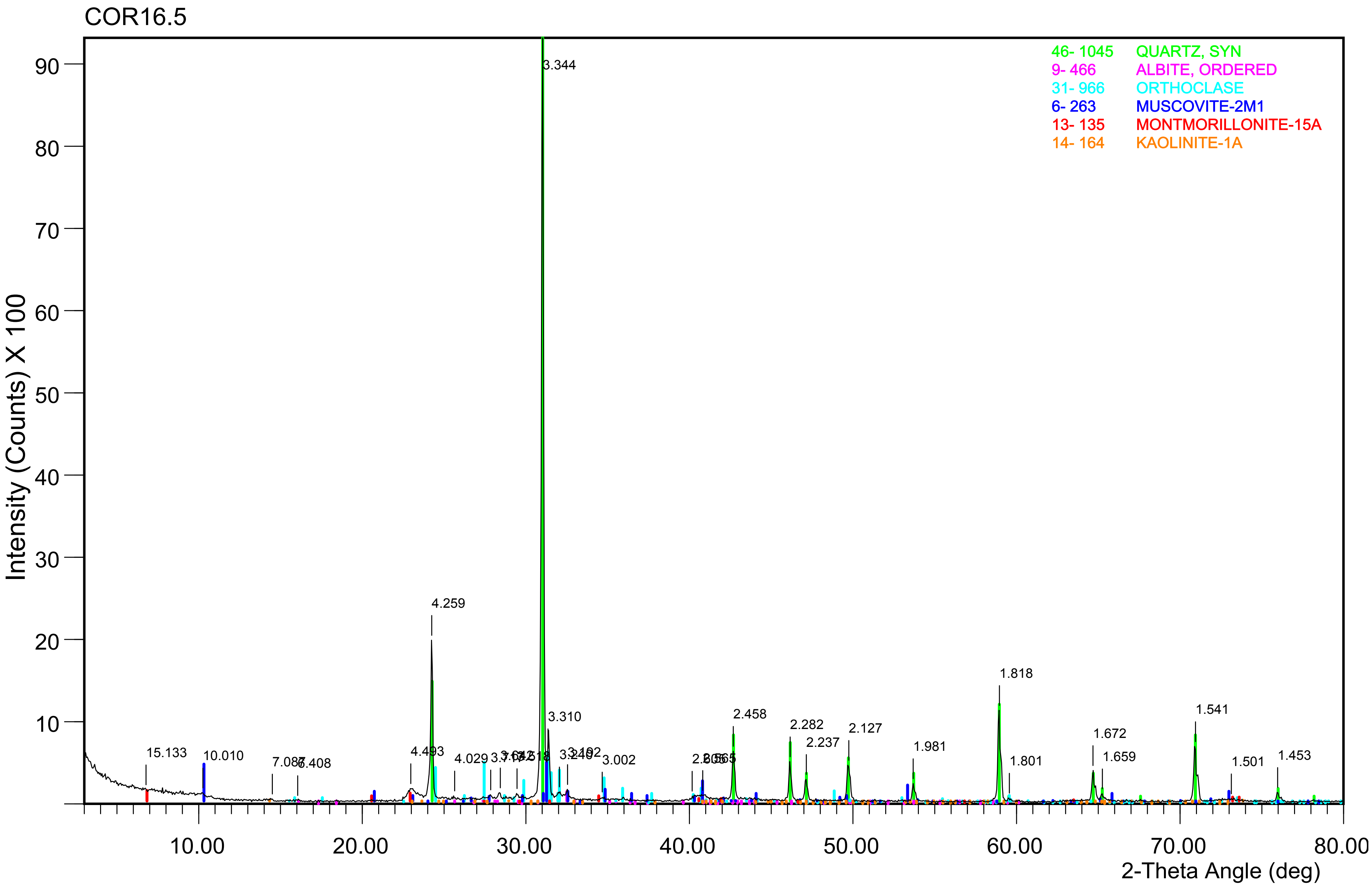
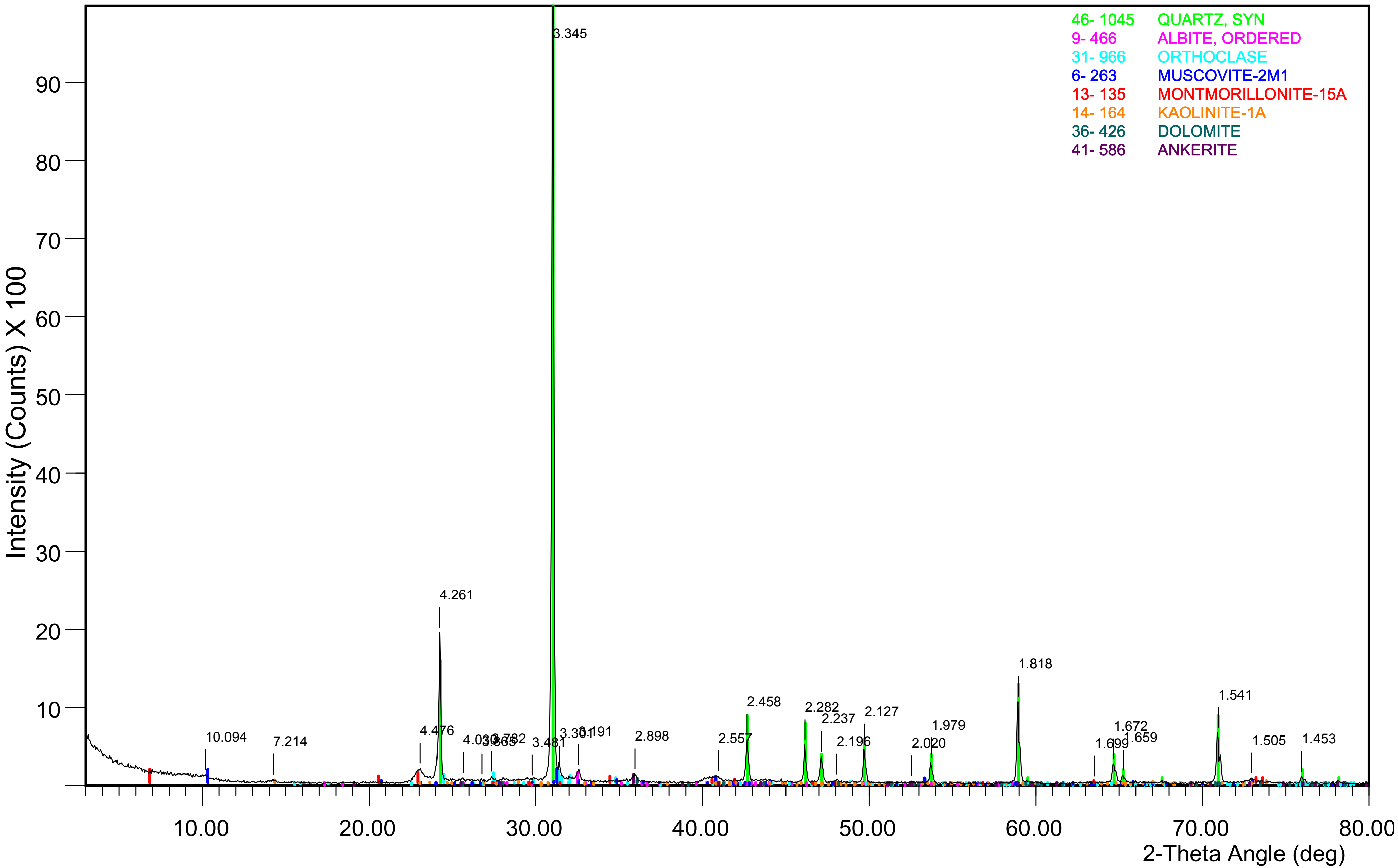


File Name: c:\...\17392blk.016

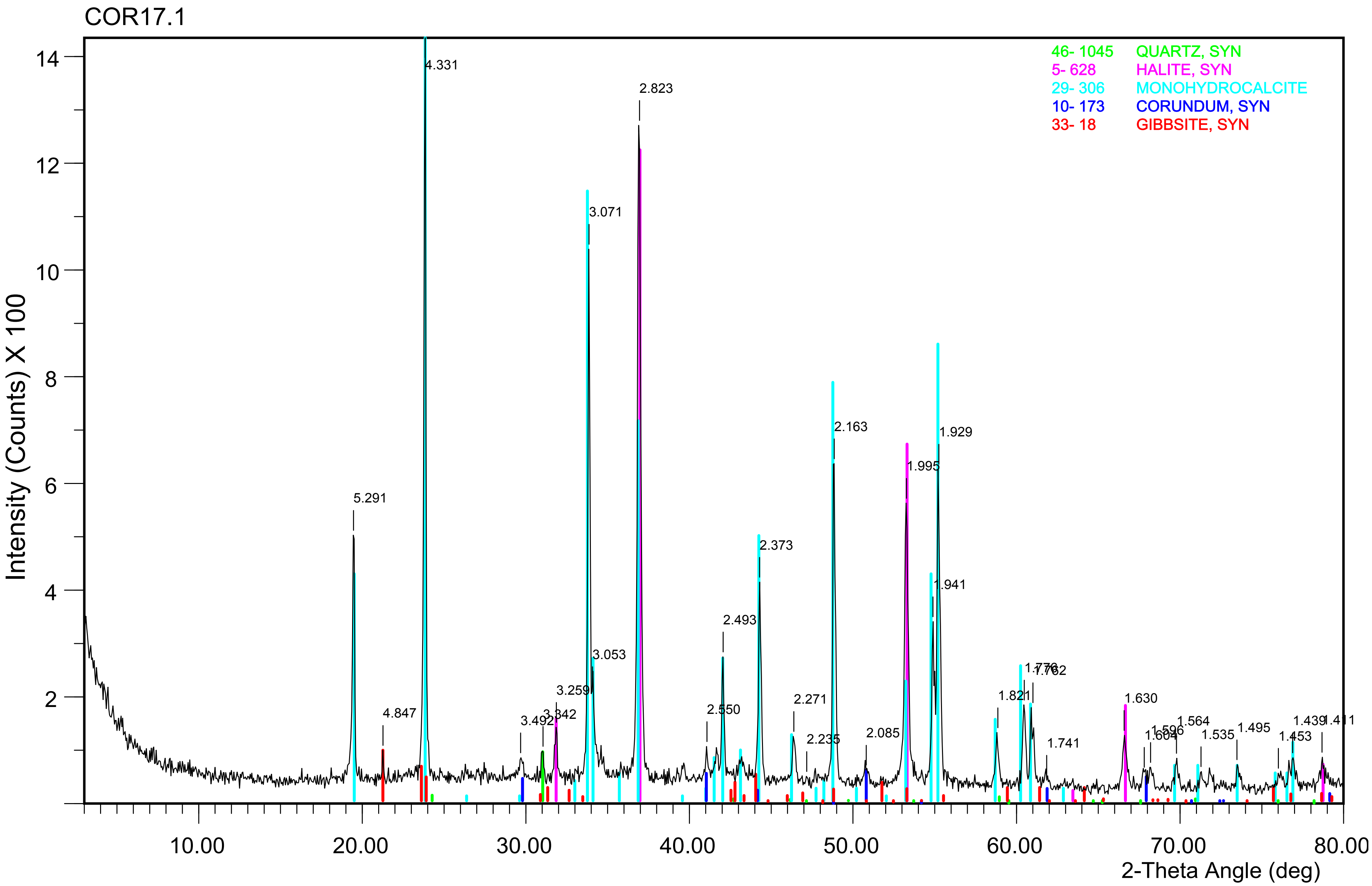
CSIRO Land and Water

COR16.6



File Name: c:\...\17393blk.017

CSIRO Land and Water



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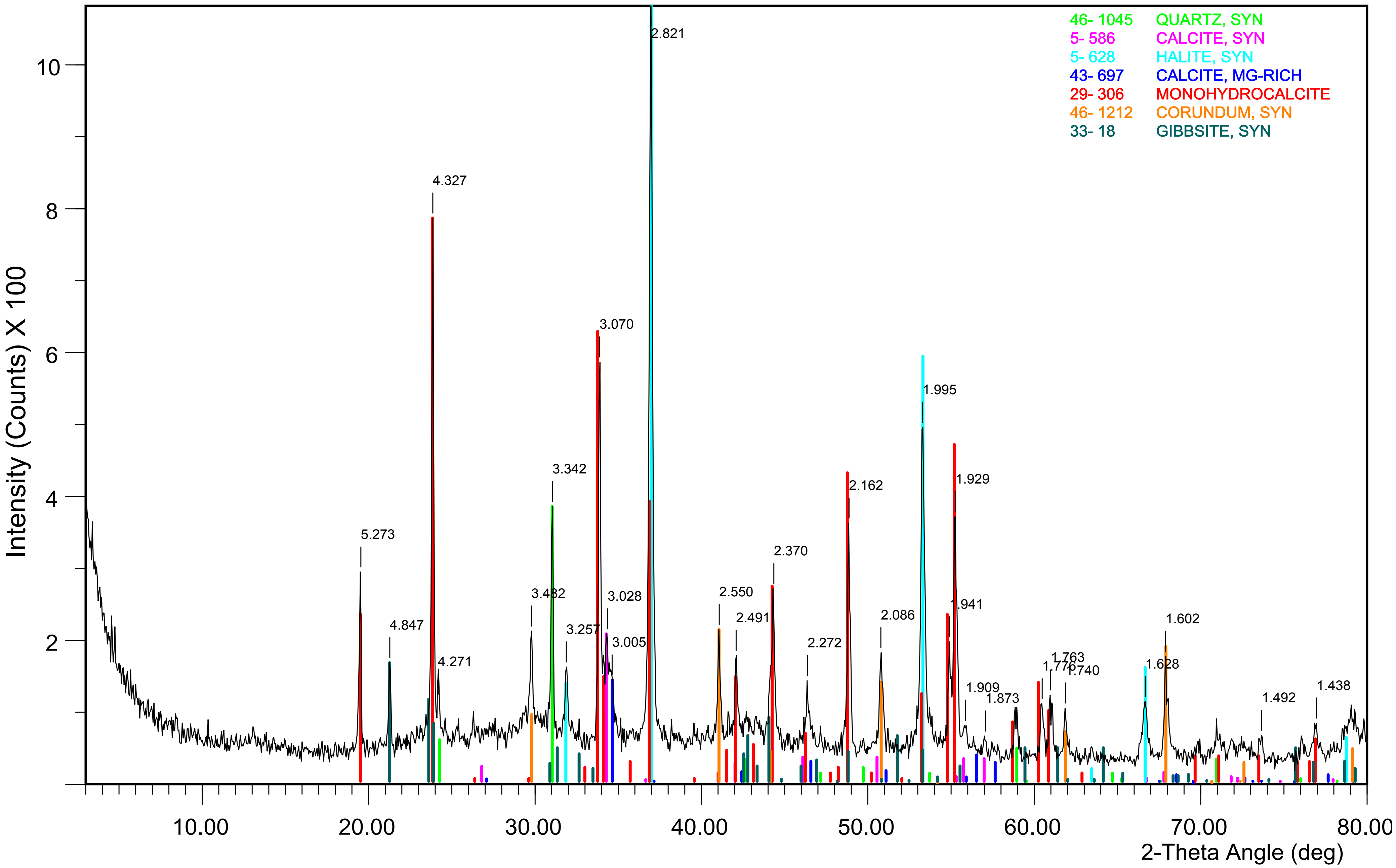
COR17.2



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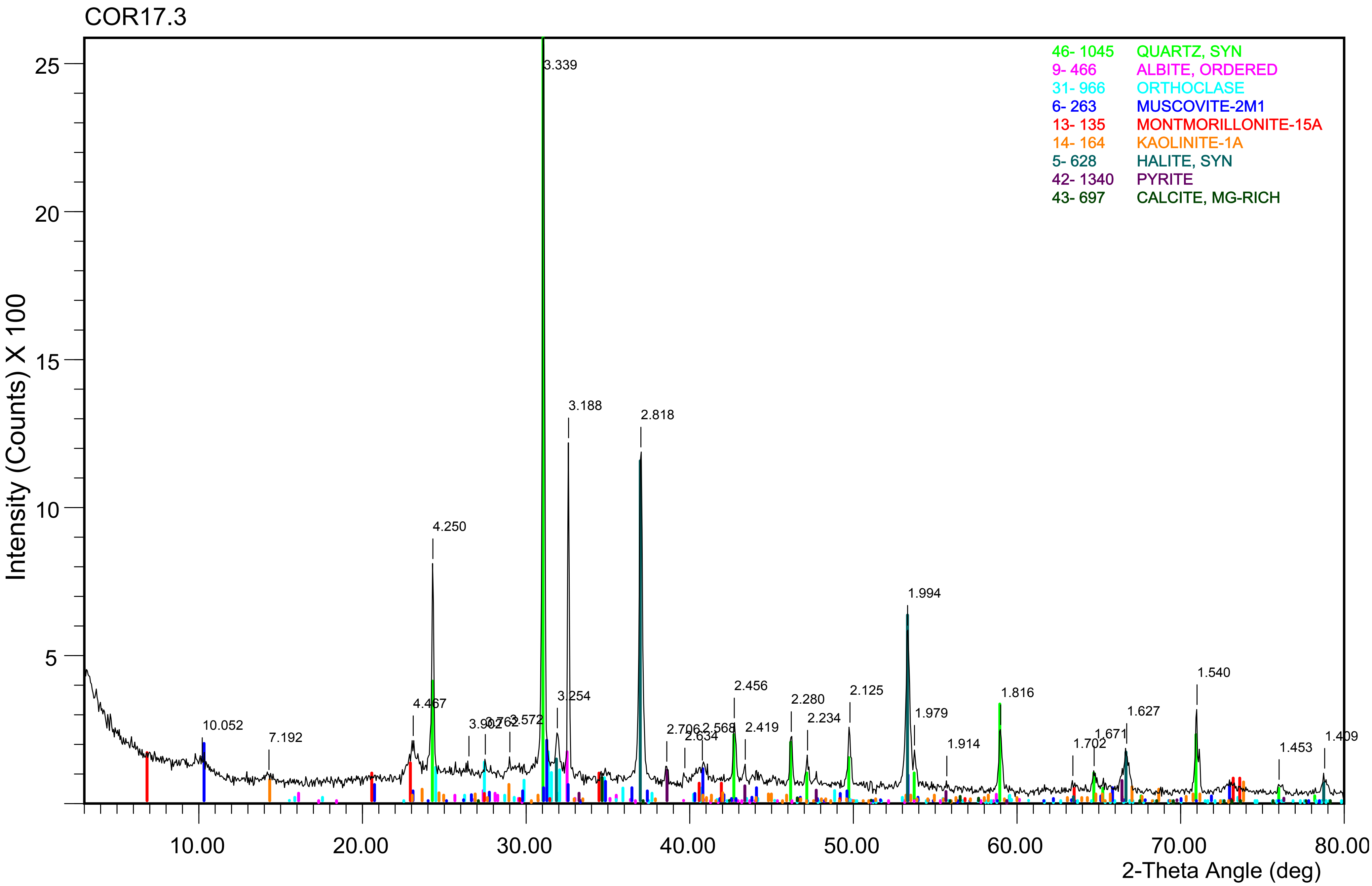

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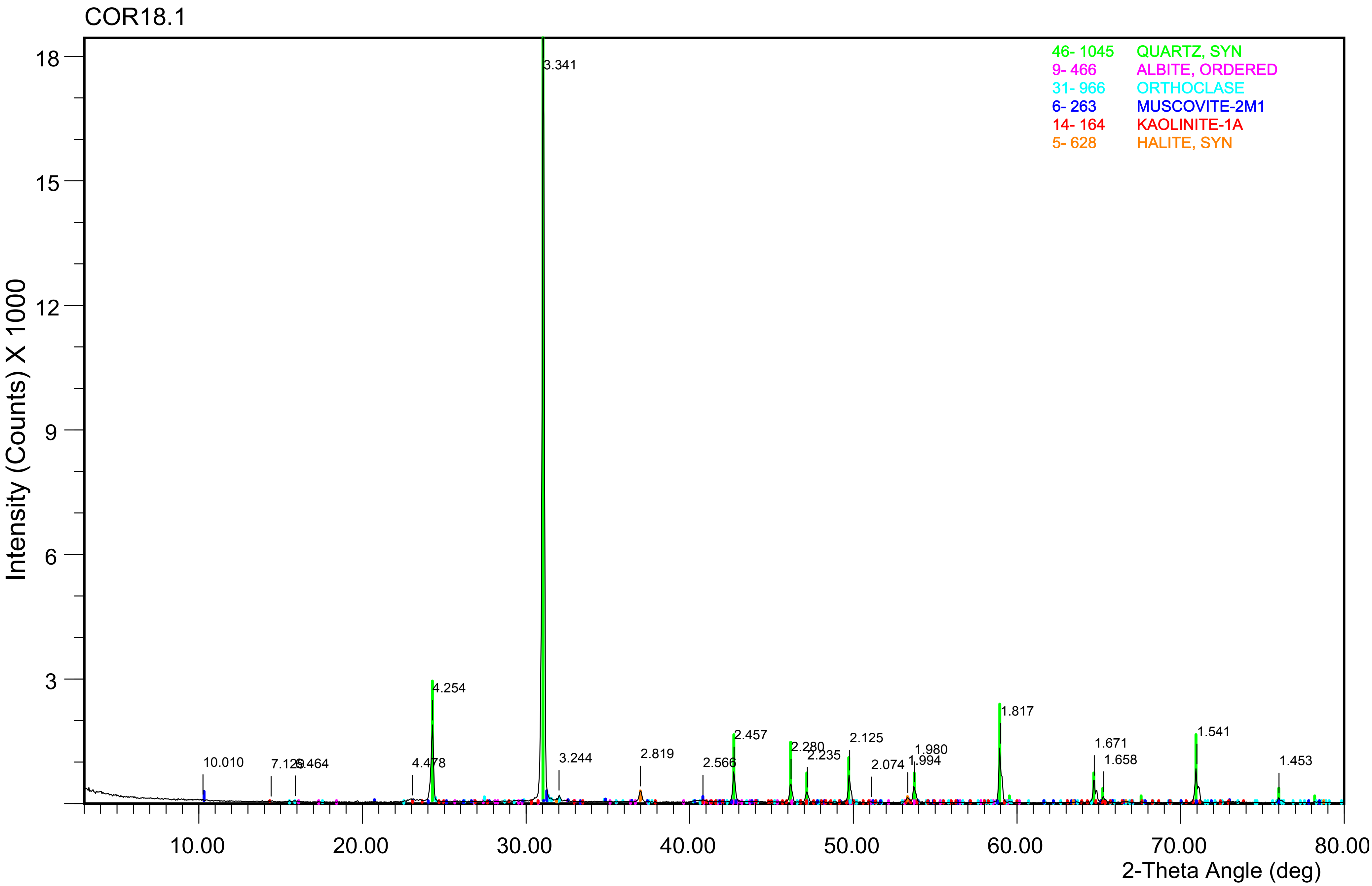

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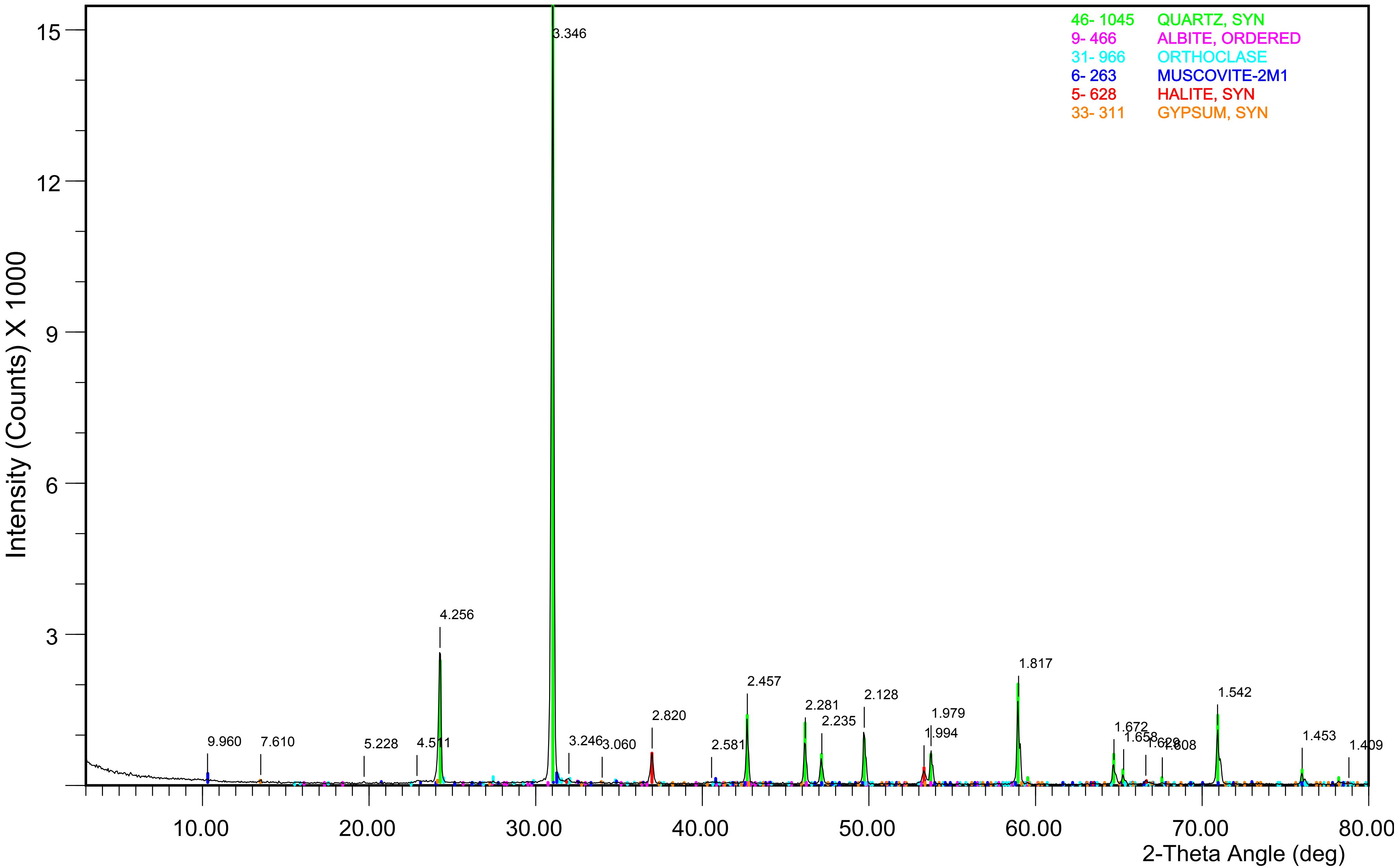
COR18.2



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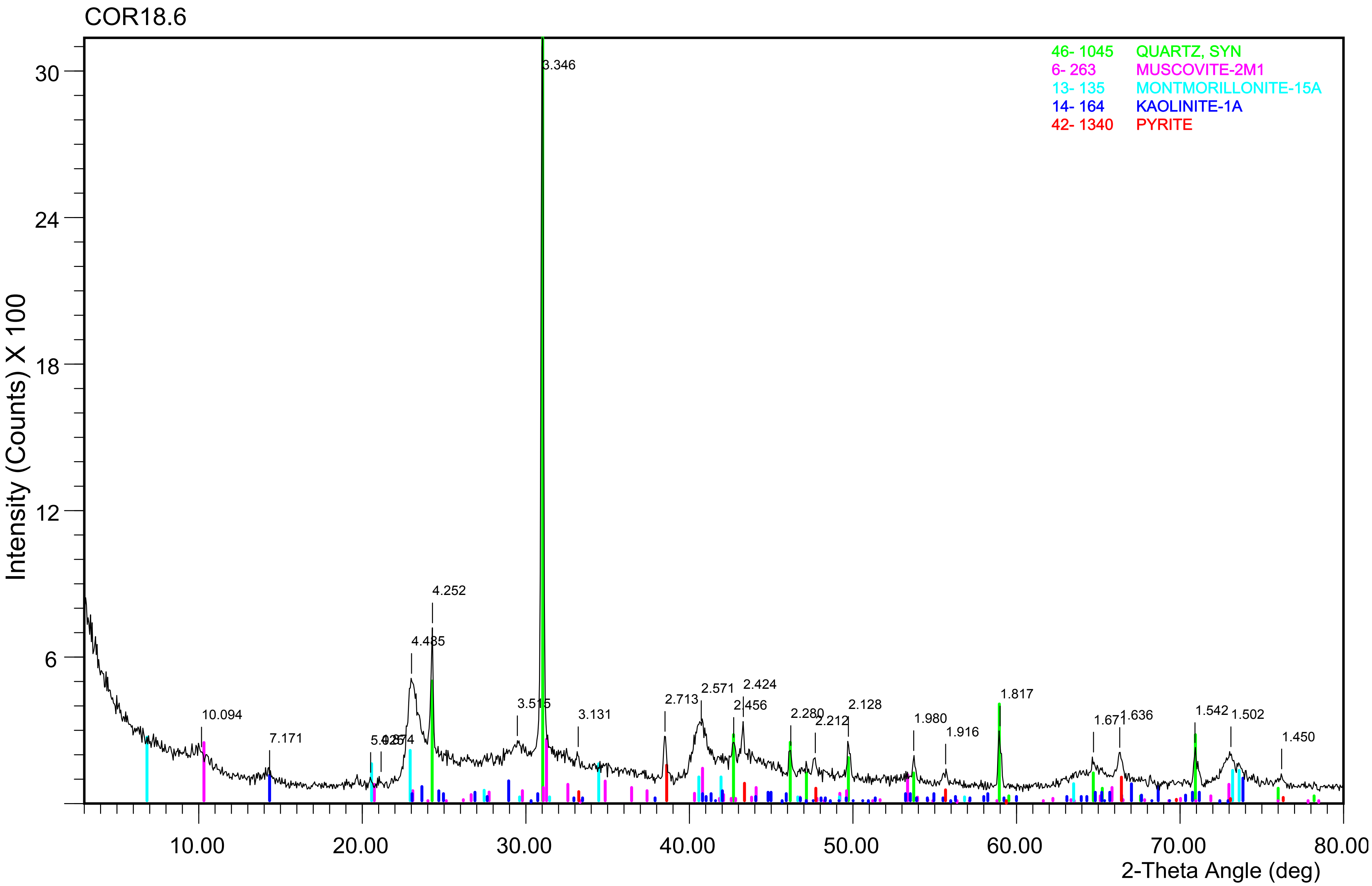
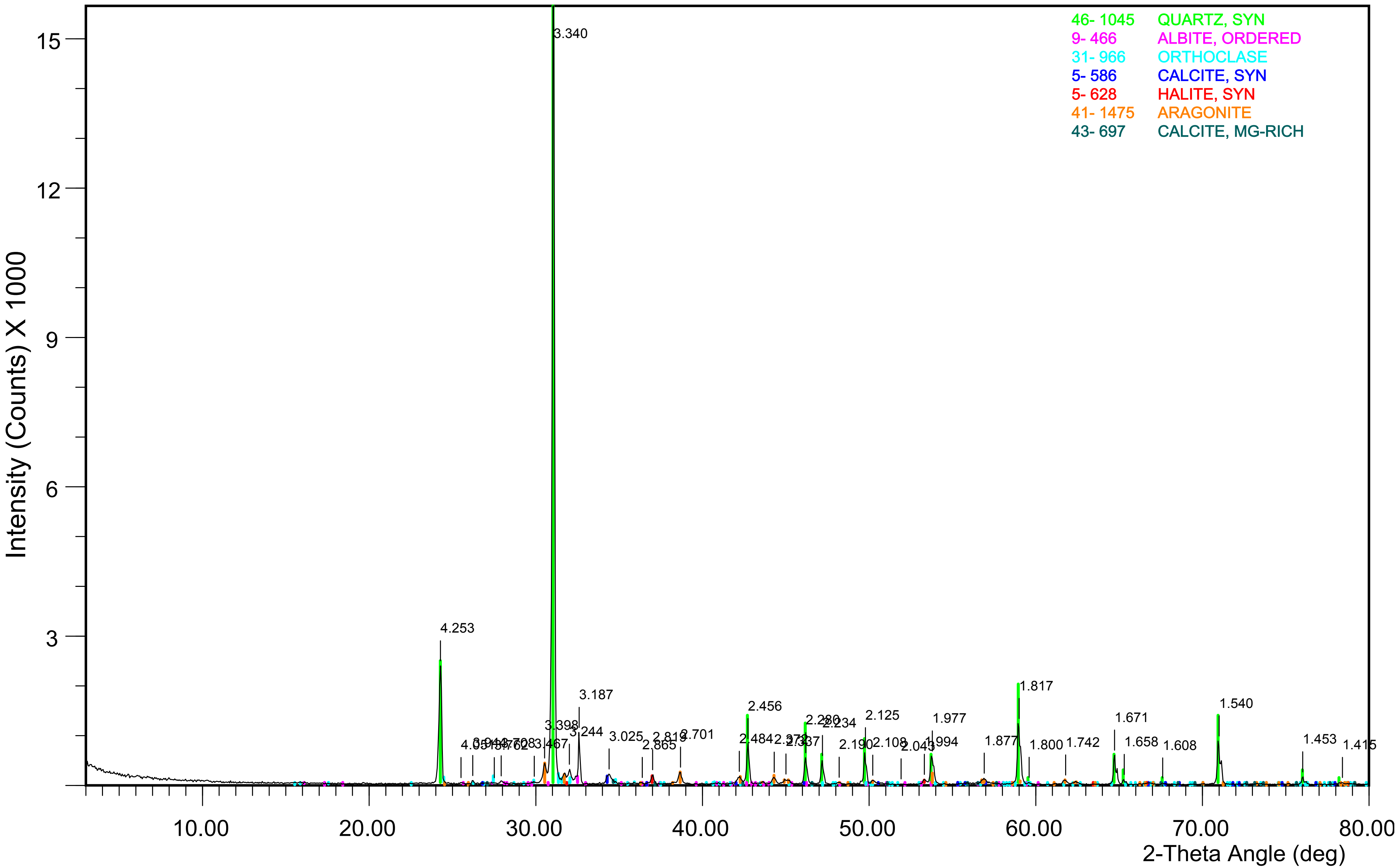


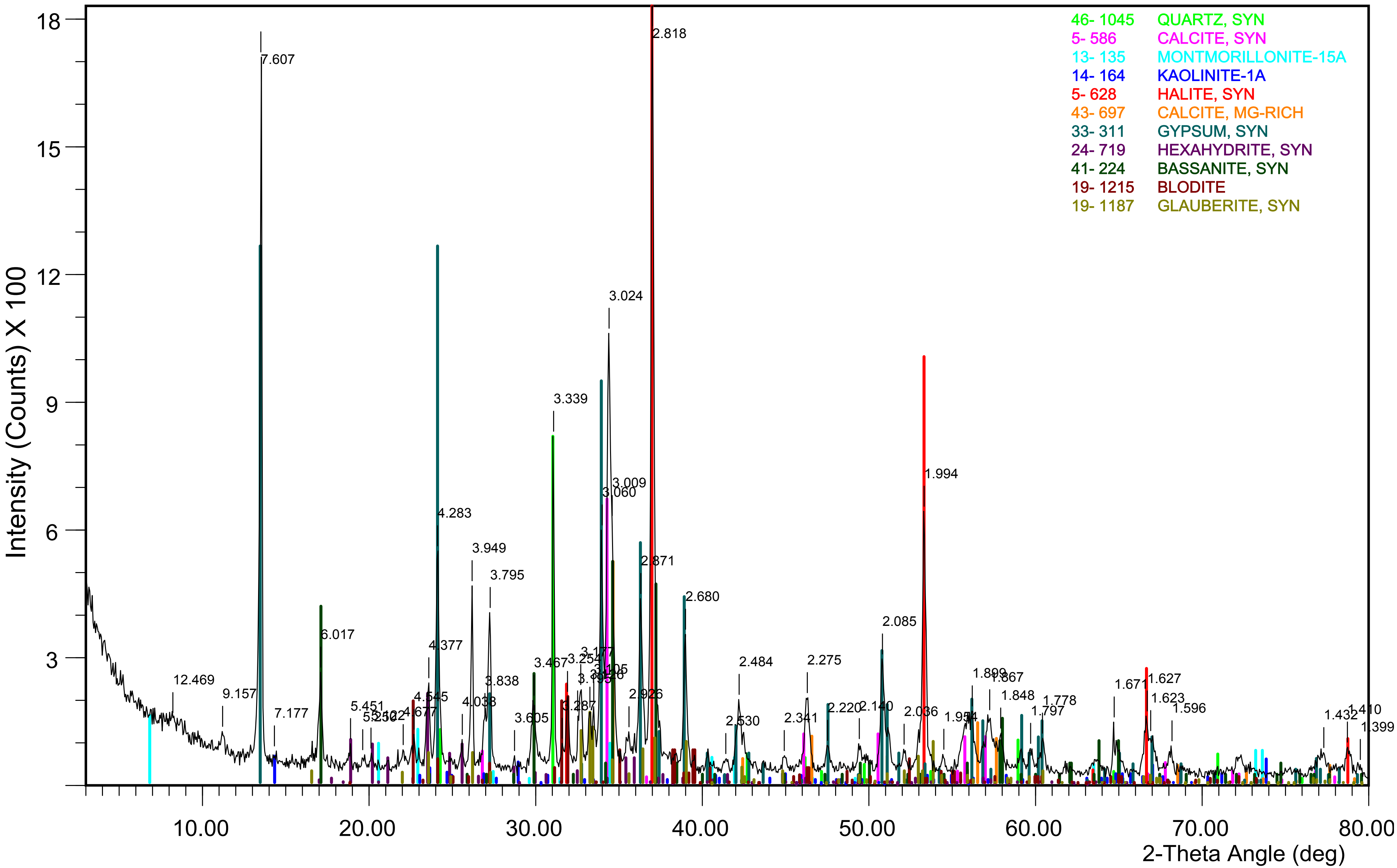
File Name: c:\...\17401blk.003

COR20.1



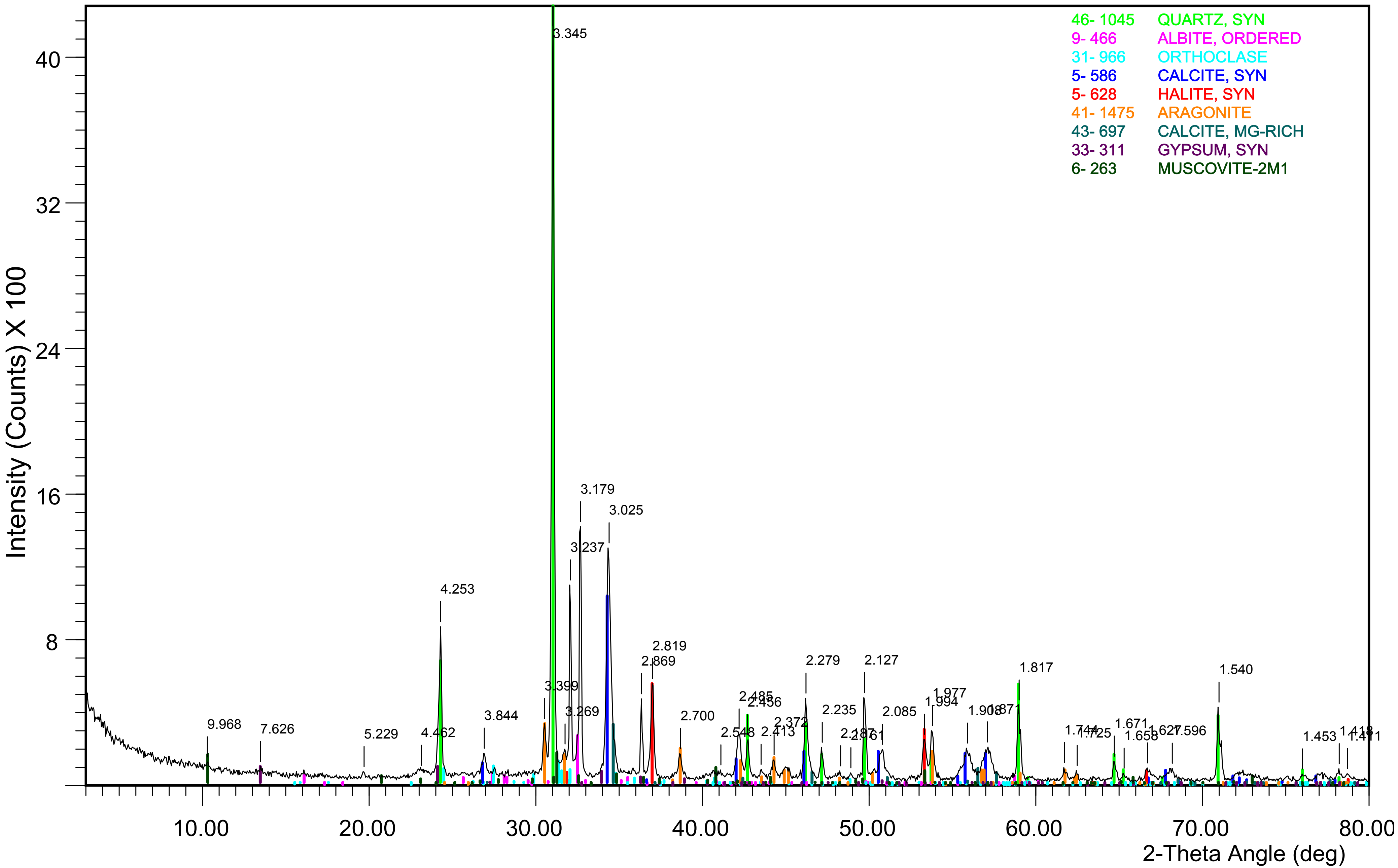
File Name: c:\...\17405blk.004

COR21.1



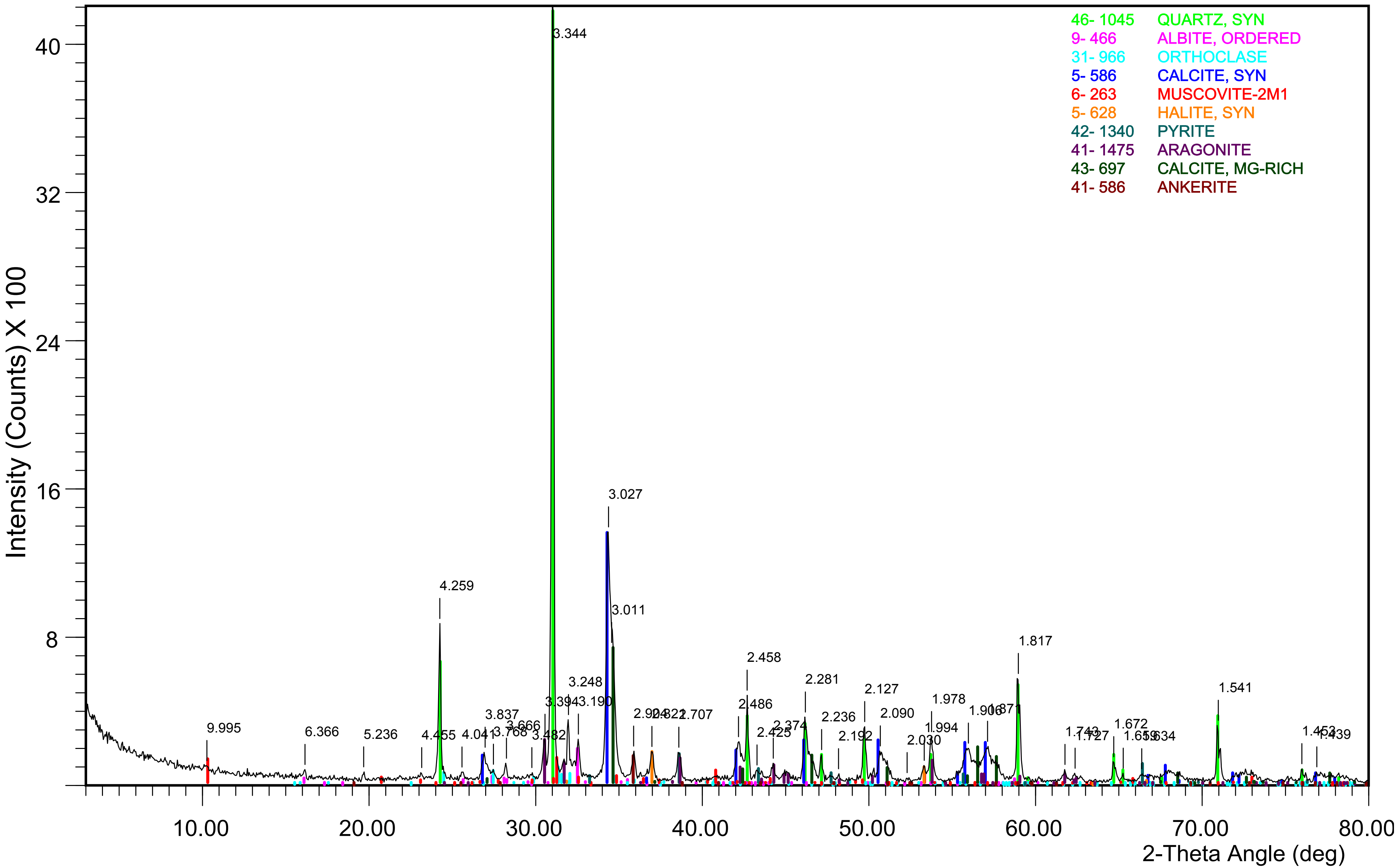
File Name: c:\...\17406blk.005

COR21.2



File Name: c:\...\17407blk.006

COR21.4



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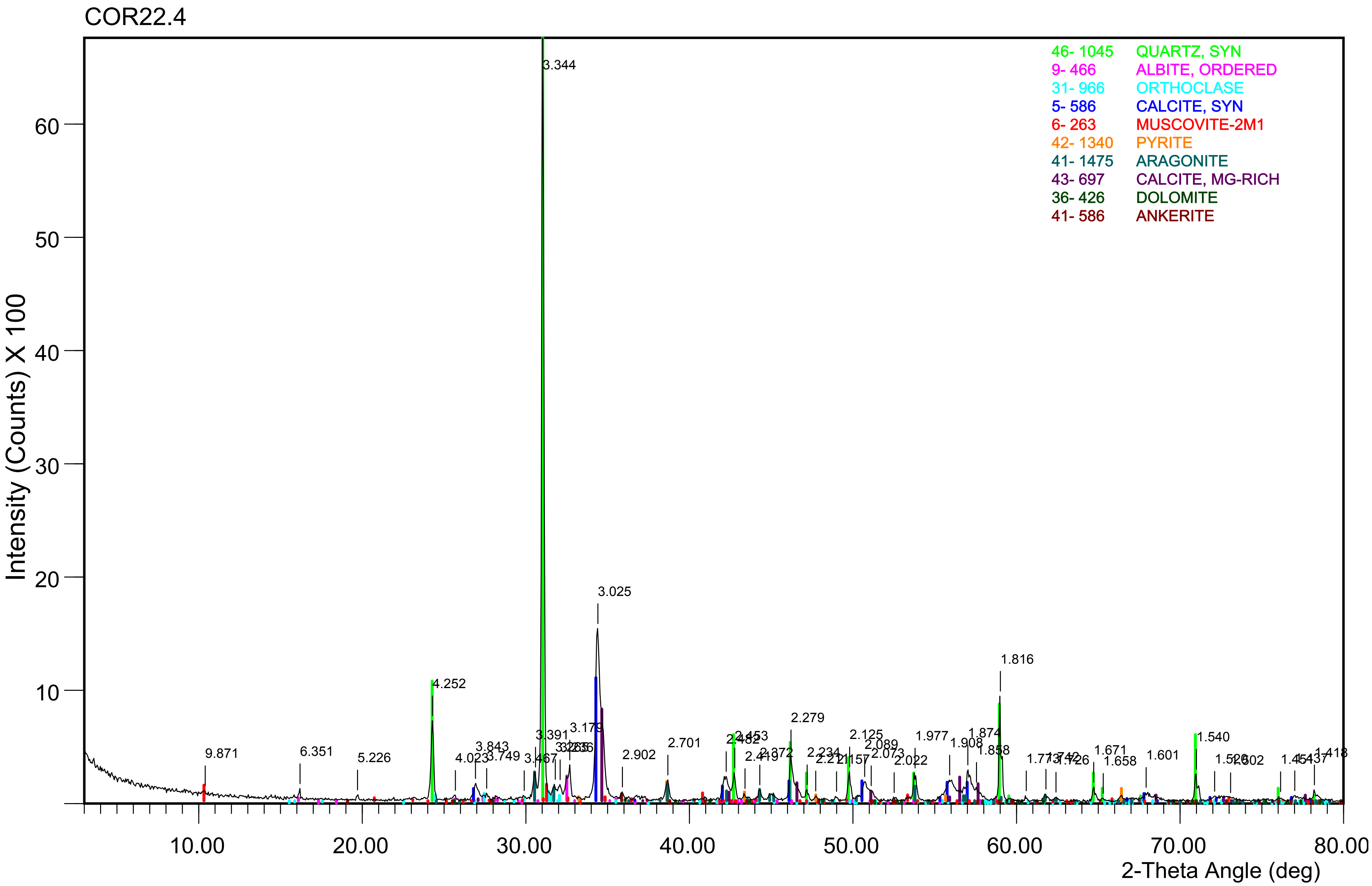
CSIRO Land and Water



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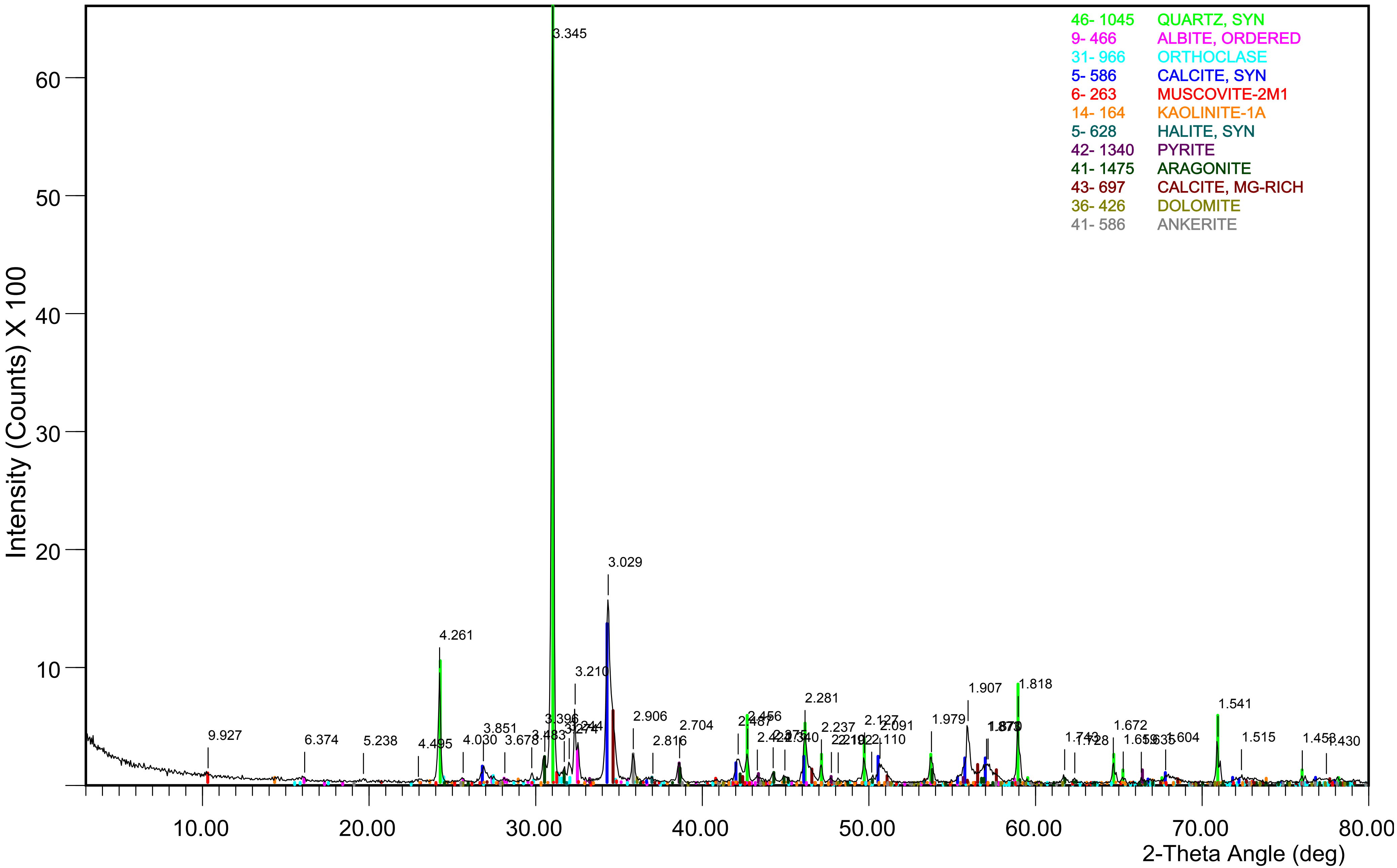
CSIRO Land and Water

COR22.5



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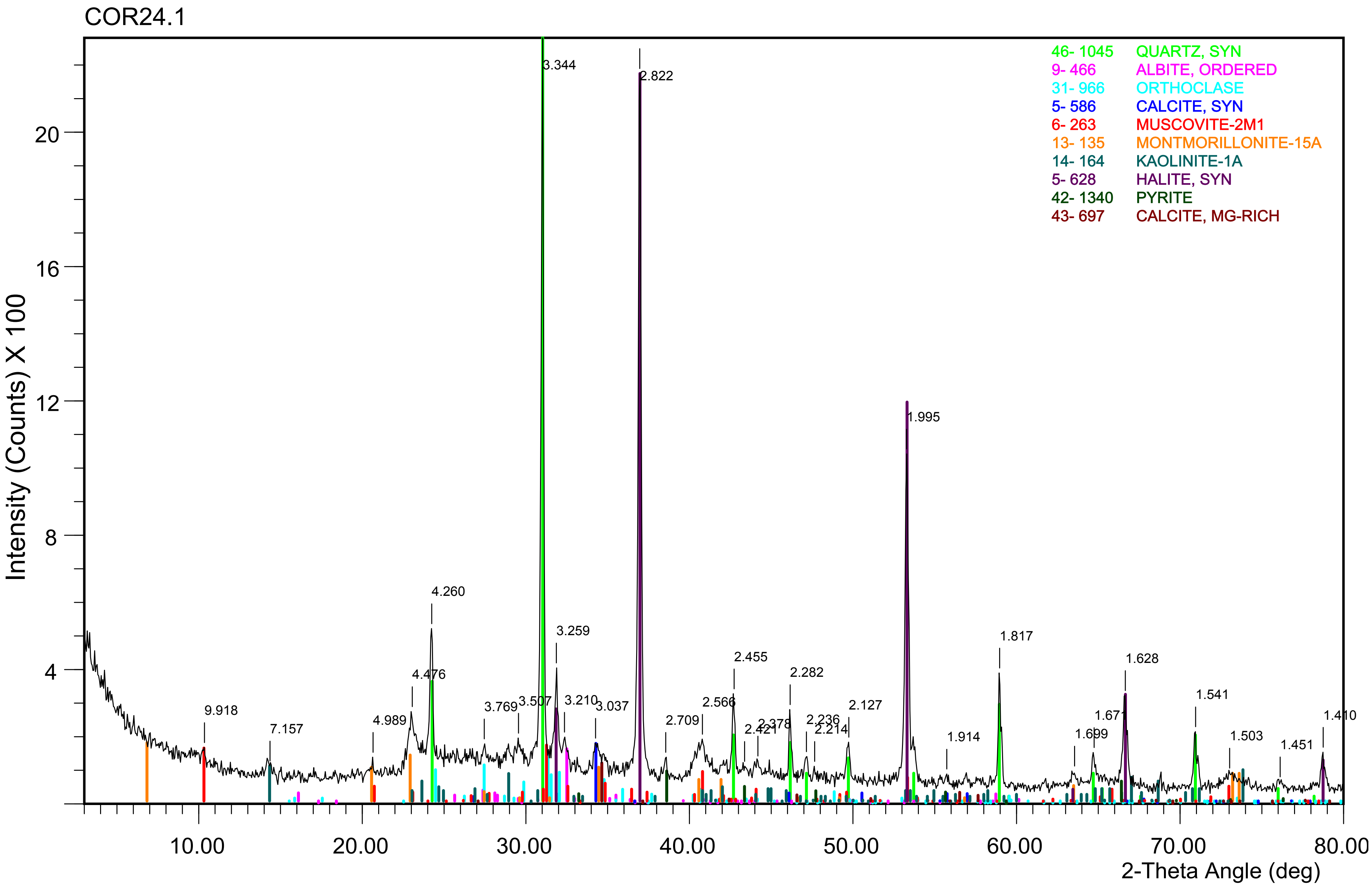
CSIRO Land and Water



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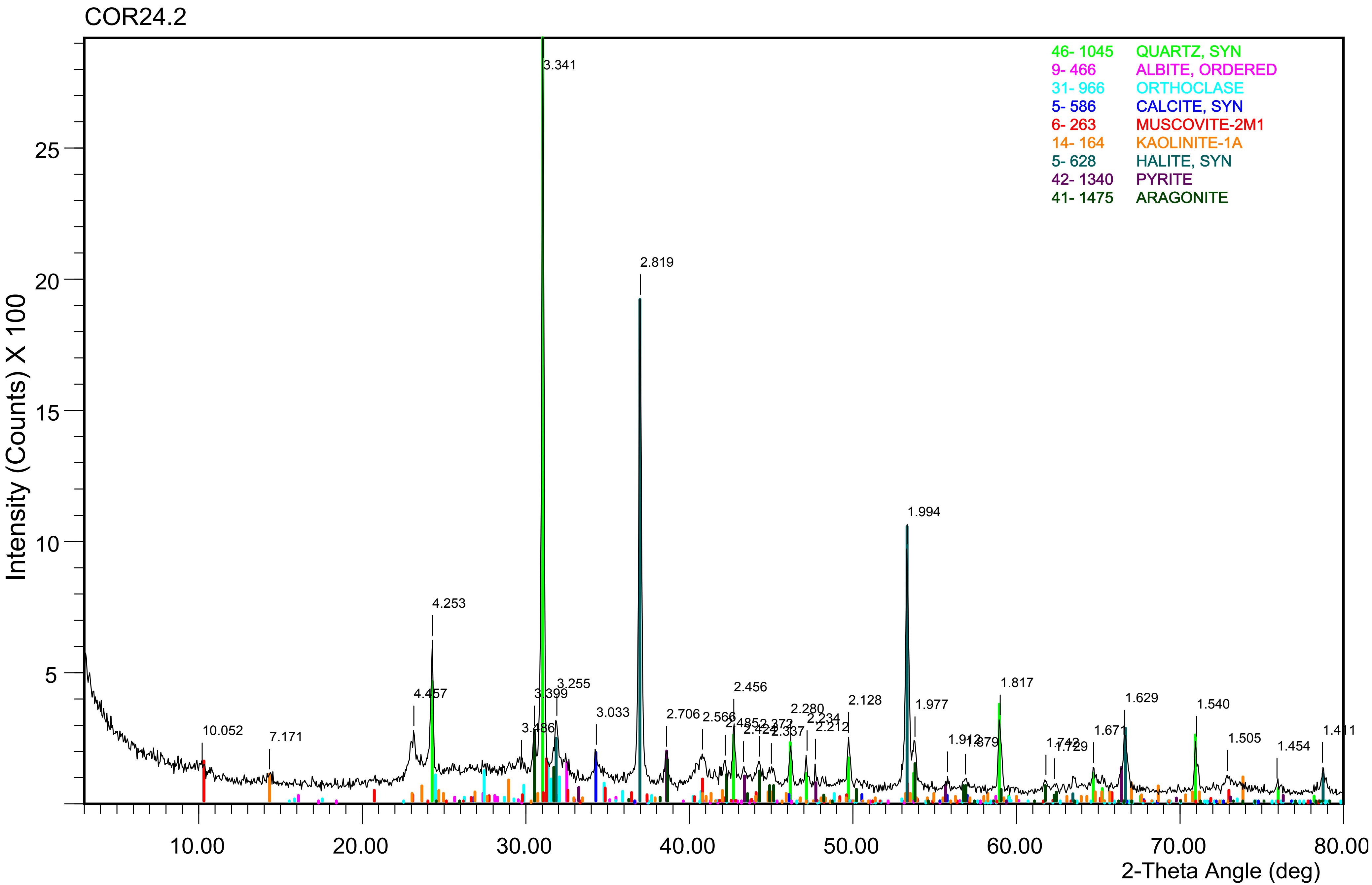

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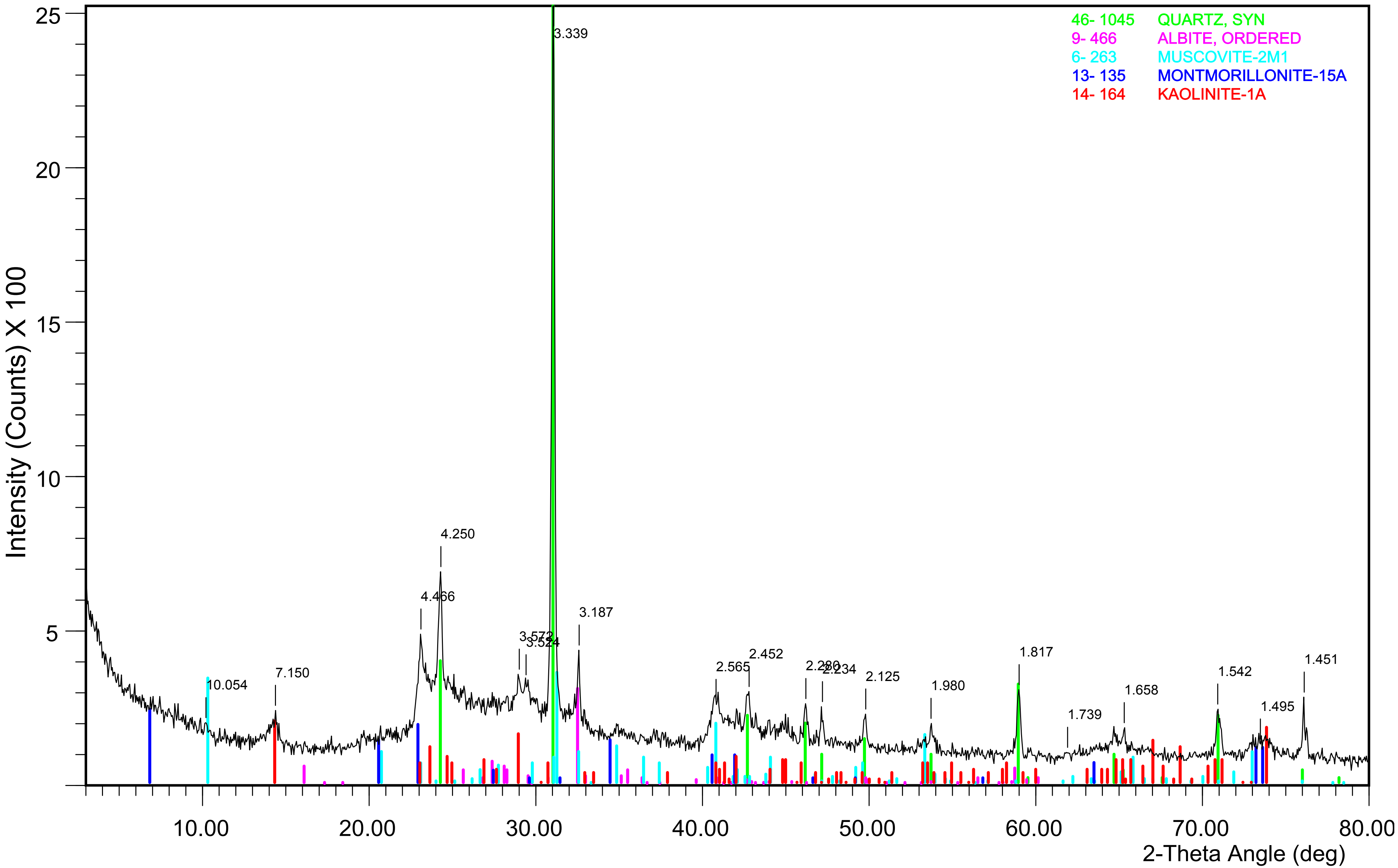
COR28.2



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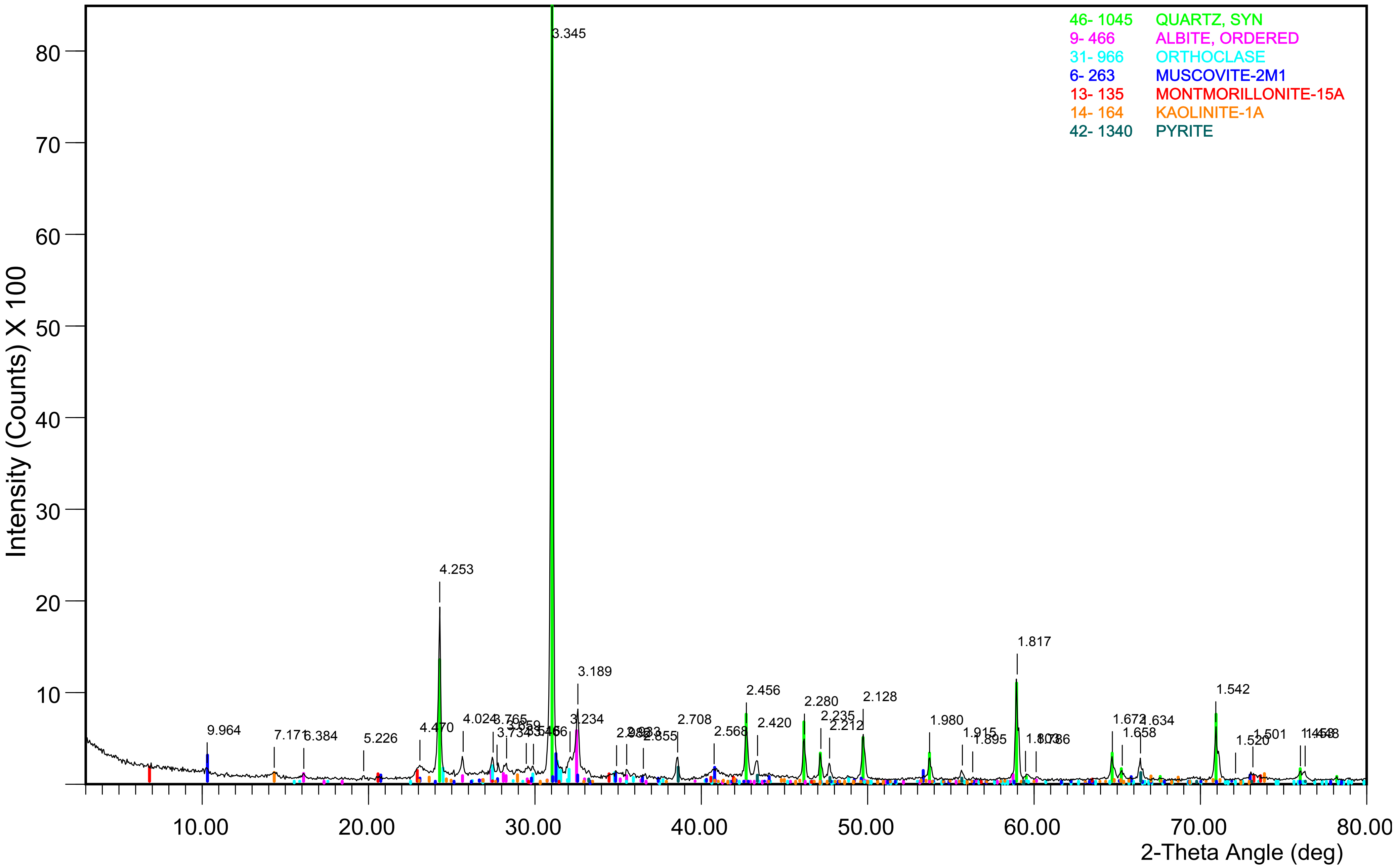
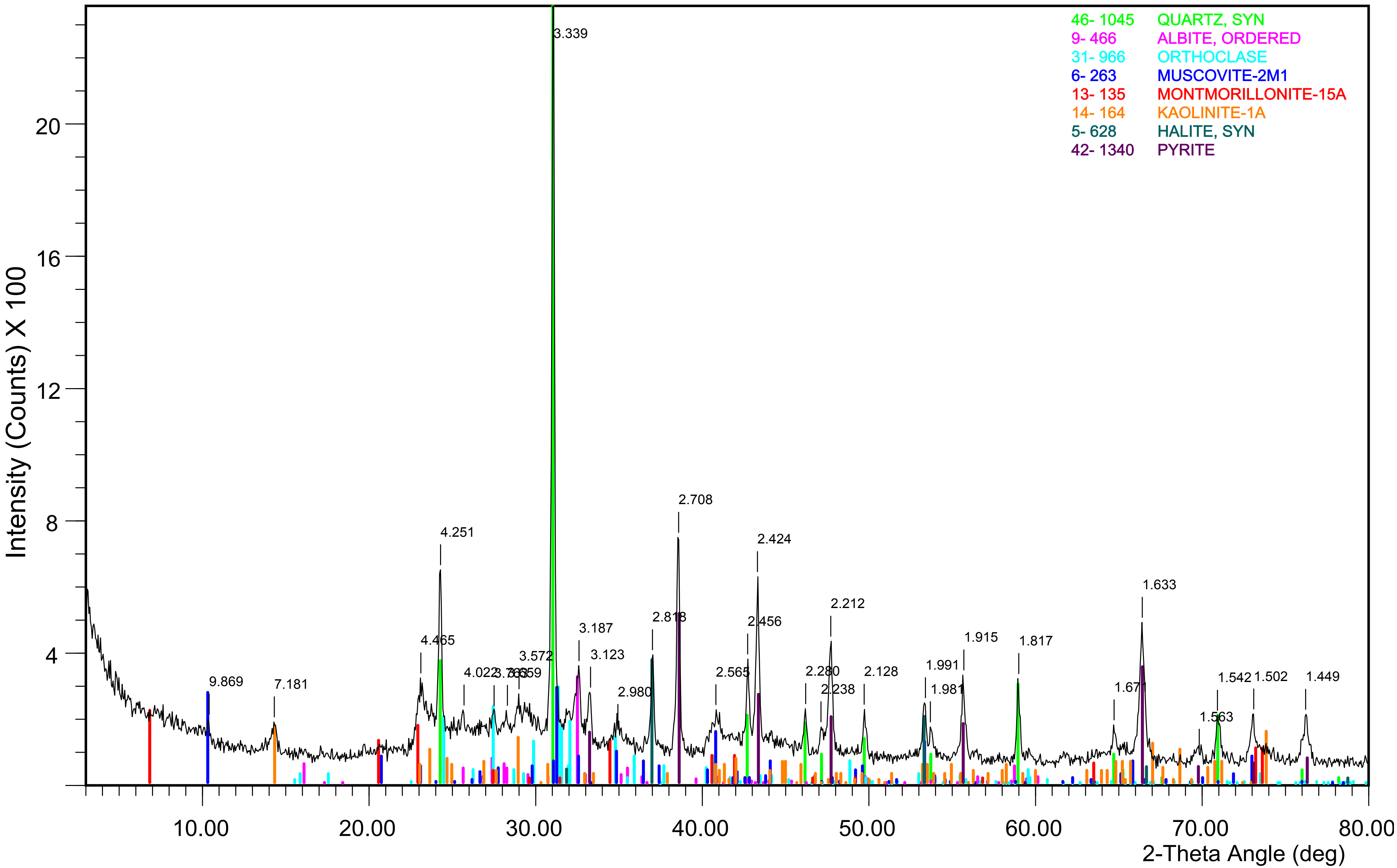
COR28.3



File Name: c:\...\17434blk.013

COR29.3



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